AD-774 506

WEBSEC-70, AN ECOLOGICAL SURVEY IN THE EASTERN CHUKCHI SEA

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Coast Guard
Washington, D.C.

December 1972

BIBLIOGRAPHIC DATA SHEET	1. Report No. CG-373-50	2. AD774506	3. Recipient's Accession No.
4. Title and Subtitle WEBSEC-70, An Ecological Survey in the Eastern Chuckchi Sea September-October 1970			5. Report Date December 1972
			6.
7. Author(s) Merton C. Ingham; Bruce A. Rutland; et al.			8. Performing Organization Rept. No. CG-373-50
9. Performing Organization Name and Address Coast Guard Oceanographic Unit Building 159-E, Navy Yard Annex Washington, D. C. 20390			10. Project/Task/Work Unit No.
			11. Contract/Grant No. N/A
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered Oceanographic (Ecological) SEP-OCT 70
			14.

15. Supplementary Notes

16. Abstracts

Oceanographic stations were occupied by the USCGC GLACIER in the eastern Chukchi Sea during 25 September - 17 October 1970. The currents and distributions of physical and chemical variables are described. Geologic sampling was carried out in the same area, using a variety of field techniques to define the sediment distribution pattern and particle transport processes. Water turbidity, bottom sediments along with current measurements and water mass data are discussed.

Pelagic bird and mammal observations were made in the area from 22 September to 17 October 1970, providing new fall distributional and feeding information for the biologically little known area from Point Barrow to Cape Lisburne.

(Continued on back)

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 224
Releasable to the Public	20. Security Class (This Page) UNCLASSIFIED	22. Price $14.25

Block No. 16 (Continued)

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Sixty two categories of zooplankton were identified from 77 vertical net tows with the results of the data summarized in two tables and three charts. Fish were collected on 20 stations. Lists of species captured are present.

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REPORT No. 50 CG 373-50

WEBSEC-70

AN ECOLOGICAL SURVEY IN THE EASTERN CHUKCHI SEA

September-October 1970

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WASHINGTON, D.C. DECEMBER 1972

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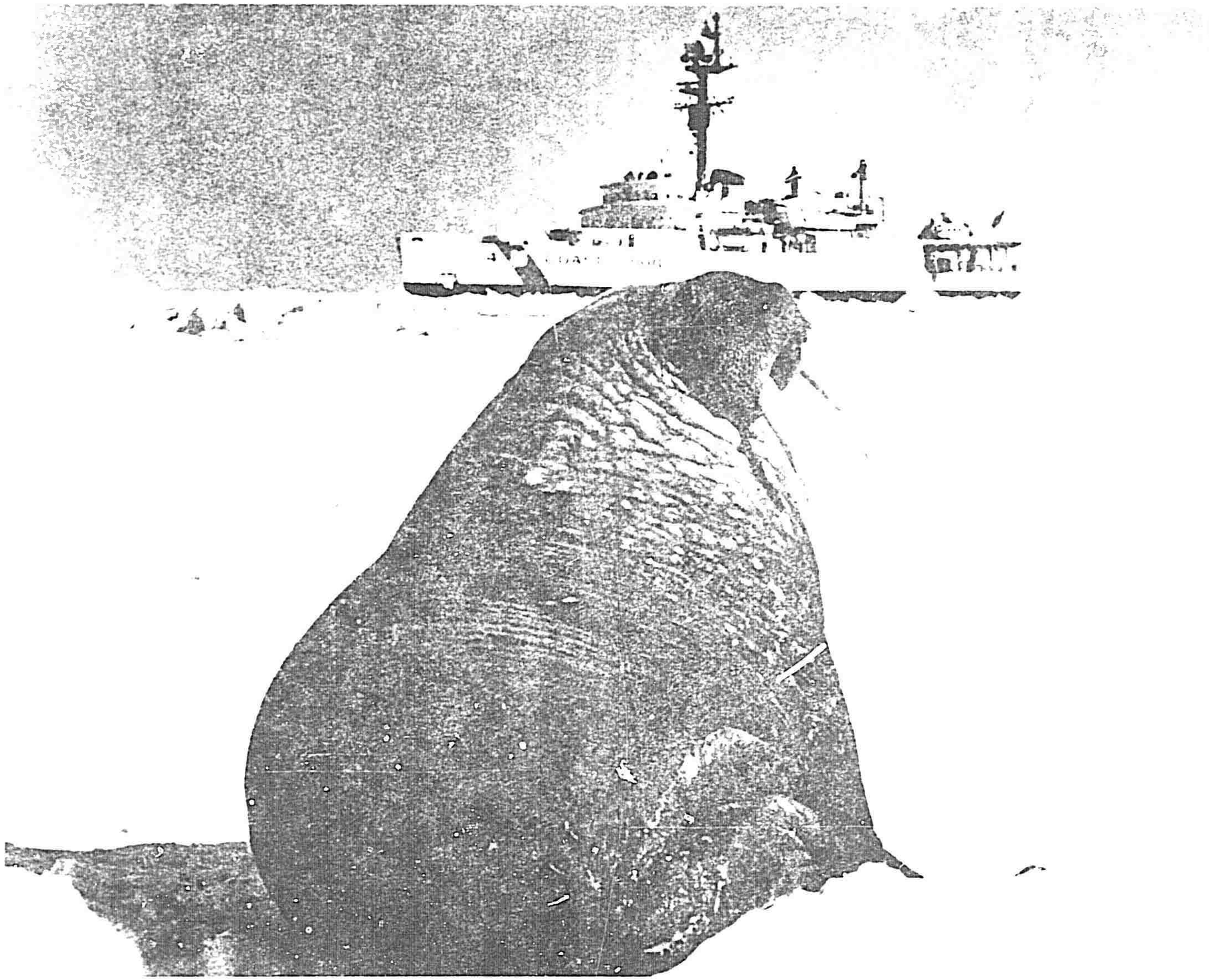

Frontispiece: USCGC GLACIER (WAGB-4) and Walrus (*Odobenus rosmarus*.)
Photograph by David R. Moore, LTJG, USCG.)

Abstract

Oceanographic stations occupied by USCGC GLACIER in the eastern Chukchi Sea during 25 September–17 October 1970 revealed that currents and the distributions of physical and chemical variables were strongly influenced by the effects of wind and cooling. The effects of Alaskan coastal runoff, melting of sea ice. freezing of sea ice, and bottom water from the central Bering Strait were observed. Distributions of dissolved nutrients showed horizontal gradients which may have been the result of photosynthetic activity. Currents were strongly influenced by the northeasterly winds and showed the expected northeastward set only on two stations, when the winds were weak and variable. Currents near shore between Cape Lisburne and Icy Cape were weak and variable, suggesting the possibility of an eddy or pocket of slack water "downstream" from Cape Lisburne.

Geologic sampling was carried out in the same area, using a variety of field techniques to define the sediment distribution pattern and particle transport processes. Water turbidity, bottom sediments, current measurements, and water mass data suggest that fine material is transported northward from the Bering Strait through the eastern Chukchi Sea to the Arctic Ocean. Fine particulate matter moves near the bottom along the eastern side of the trough between Herald Shoal and the Alaskan coast. Over shallower portions of the shelf, convective overturn and wind mixing circulate suspended material throughout the water column during the fall. The coincident association of a muddy bottom with the zone of highest turbidity indicates sedimentation from northward-flowing waters. The lack of pebbles in these muds indicates that ice rafting is not, at present, an important mode of sediment deposition here. Considerable interaction between the benthos and bottom sediments is apparent. Materials presumed to be of both modern and relict or residual origin show negligible current-produced sedimentary structures. Most turbation can be ascribed to the benthic activity of various fauna consisting of pelecypods, amphipods, echinoids, worms, and Walrus. Geochemical studies show no evidence of anomalous values of selected heavy metals or hydrocarbons.

Pelagic bird and mammal observations in the eastern Chukchi Sea during WEBSEC–70, September 22 to October 17, 1970, provide new fall distributional and feeding information for the biologically little-known area from Point Barrow to Cape Lisburne. Additional observations were made during a 1-day transect through the Bering Strait, October 18. Throughout the cruise, a total of 36 species of birds and 7 species of mammals was seen. Observations are presented on maps for most of the species and these are compared in the text with previously published records. Fall migration or post-breeding dispersal was still underway for loons, Oldsquaw and eider ducks, gulls, alcids, and Walrus, but shearwaters, fulmars, pond ducks, geese, phalaropes, jaegers, terns and Grey Whales had either already left the area before cold weather, or did so early in the cruise. Birds and Walrus were relatively abundant at sea with Ivory and Ross' Gulls unexpectedly common. An observed vagrant Skua, prob-

ably from the Antarctic, is the northernmost Pacific sector record of this species. A small number of collected specimens of birds yielded stomach content information, ectoparasites and tissue samples for pesticide and heavy metal analysis.

Preliminary results of studies of sedimentation, macrobenthic population and trace transition metal chemistry of sea water of the east central Chukchi Sea are described. Notable vertical variations in the texture of the core sediments are observed. Beach sediments consist of well rounded moderately well to very poorly sorted sandy gravels with bi- to polymodal size distributions; their texture suggests a complex denositional history. Near-shore sediments are primarily sandy muds with occasional presence of ice-rafted (?) gravels. Distributions of clay minerals suggest that chlorite has its source in the adjacent land whereas smectite is most probably transported from the Chirikov Basin. Comparison of the data of this study with those of Naidu et al. (1971) shows significant differences in the relative abundances of clay minerals in the east central Chukchi Sea and the continguous western Beaufort Sea. A general increase in Na^+ with core depth in the interstitial waters is attributed to the decreased intake of it by sediments as a result of decreased clay content. However, a general increase in K^+ with depth is believed to be due to greater dissolution of feldspar and/or decreased adsorption by clays. A net decrease in Ca^{++} and Mg^{++} with depth is probably related to the increased dolomite precipitation at greater depths. Post-depositional reduction and upward migration of manganese is attributed to an increase in Mn^{++} toward the core top. The concentrations of Cu and Co in the overlying waters are slightly higher than the averages cited in sea water and are ascribed to local supply of these metals from the adjoining hinterland. However, Ni and Zn concentrations are lower compared to those generally observed in sea water.

Sixty-two categories (species and life history stages) of zooplankton were identified from 77 vertical net tows (39 stations) from the eastern Chukchi Sea, September 29–October 17, 1970. Species at each station varied from 5 to 29. Numbers of calanoid copepods varied from 27 to 3146 per 100 m^3 of water. Data are summarized in two tables and three charts.

Fish were collected on 20 stations with a 6-foot Isaacs-Kidd midwater trawl and on one station with a 10-foot, shrimp try net. Lists of species captured are presented.

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Preface

Preface

WEBSEC-70 (Western Beaufort Sea Ecological Cruise—1970) was the first of a series of cruises in the Alaskan Arctic to survey the state of the marine environment and its associated biota. It is hoped that the physical, chemical, biological, and geological data acquired on this and subsequent WEBSEC cruises will contribute to a thorough description of the marine ecosystem in a relatively unpolluted state, providing a base for assessing the impact of pollution from future increases in development, mineral extraction, and transportation.

The evolution of the concept of the WEBSEC series began with the concern held for the fate of the marine ecosystem in the Alaskan Arctic by individual scientists at the Coast Guard Oceanographic Unit (CGOU). Because Coast Guard icebreakers provide platforms needed to conduct scientific investigations in Arctic waters, it was felt that CGOU should provide the impetus for a study of the marine ecosystem. As planning progressed, however, it became apparent that CGOU's scientific and technical staff lacked the capability to deal with some of the relevant variables in an ecological survey. Inquires were made to fellow scientists in other Federal agencies, universities, and research institutions to enlist assistance in the WEBSEC series. Affirmative responses were received from most people contacted, and scientists from the U.S. Geological Survey, and Bureau of Sport Fisheries and Wildlife of the U.S. Department of the Interior, the National Marine Fisheries Service of the Department of Commerce, the Smithsonian Institution, and the University of Alaska accompanied CGOU scientists and technicians on the CGC GLACIER on WEBSEC-70.

The main objective of WEBSEC-70 was to perform an ecological survey in the Beaufort Sea with particular emphasis on the area off Prudhoe Bay. The Chukchi Sea between Point Barrow and Cape Lisburne was chosen as an alternate area of operations in the event that the polar ice pack prevented operations east of Point Barrow, which proved to be the case. The cruise was conducted in a triangular area off Cape Lisburne-Icy Cape (fig. 1), the offshore extent of which was largely determined by the location of the edge of the polar ice pack. The sampling operations accomplished (listed in table 1) and the participants responsible for processing the resulting samples and data were as follows: 47 Nansen bottle casts for temperature, salinity, and nutrients (USCG), 136 XBT

drops (USCG), 14 Niskin bottle casts for geochemical and nutrient water samples (University of Alaska), 28 current meter lowerings for 130 hours (USGS and USCG), 68 transmissometer lowerings (USGS), surface meteorological observations (USCG), 77 vertical zooplankton tows (NMFS), 81 mid-water trawls (NMFS), 33 box cores (USGS), 12 metal-free gravity cores (University of Alaska), 4 piston cores (University of Alaska), 42 bottom camera lowerings (USGS), 14 beach profiles (USGS), 100 hours of bird and mammal survey (Smithsonian, BSFW), 66 birds collected (Smithsonian, BSFW), and 4 microplankton tows (USGS).

This oceanographic report is intended to be a compilation by the participating scientists of the results and preliminary interpretations of WEBSEC-70. Although this report may be considered a publication and should be cited as such, it is not intended to be the sole publication resulting from WEBSEC-70. The main objective of the report is to provide a source document to be used as a basis for further research by participating scientists leading to other publications concerning the marine ecosystem of the southeastern Chukchi Sea.

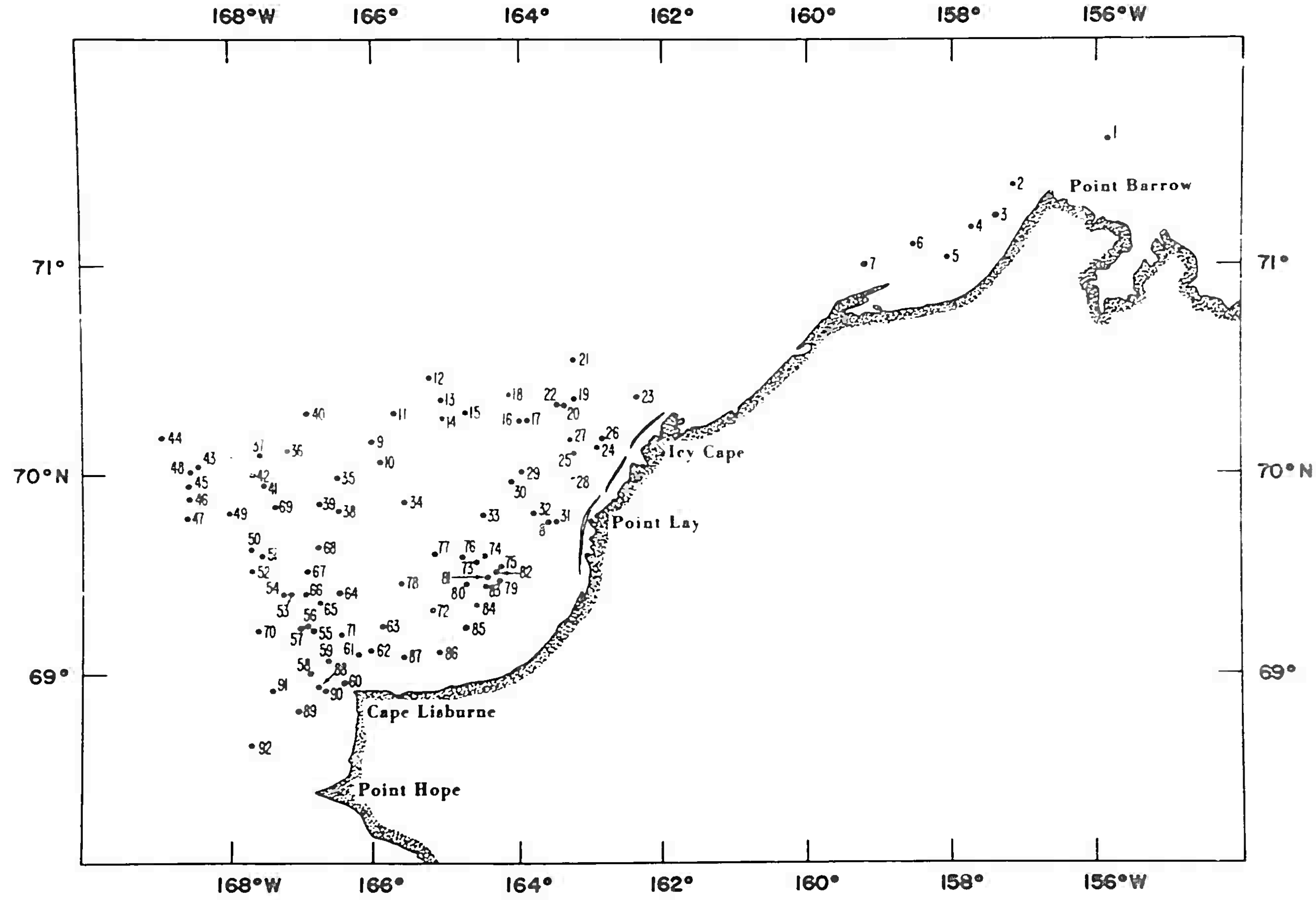

Figure 1.—Location of sampling stations during WEBSEC-70.

Table 1.—Summary of Station times, positions, and sampling operations on WEBSEC–70.

Station	Date/Time (GMT)	Position	Activities [1]
1	Sept. 23/1900	71°35′ N., 155°50′ W	BG
2	24/0114	71°22′ N., 157°09′ W	BG, XBT
3	24/0528	71°14′ N., 157°22′ W	BG, XBT
4	24/1714	71°10′ N., 157°42′ W	BG, XBT
5	24/1846	71°02′ N., 158°02′ W	BG, XBT
6	24/2036	71°06′ N., 158°31′ W	BG, XBT
7	24/2255	71°09′ N., 159°12′ W	BG, BS, XBT
8	25/1944	69°45′ N., 163°34′ W	NAC, NIC, BG, BS, VPT, T, BC, CM, XBT
9	28/0005	70°10′ N., 166°03′ W	NAC, NIC, BG, BS, VPT, T, BC, GC, CAM, XBT
10	28/0804	70°04′ N., 165°57′ W	MWT, XBT
11	28/1630	70°19′ N., 165°45′ W	NAC, NIC, BG, BS, VPT, T, BC, GC, CAM, XBT
12	29/0050	70°28′ N., 165°15′ W	NAC, NIC, BG, VPT, T, BC, GC, CAM, XBT
13	29/0954	70°22′ N., 165°06′ W	T, BC, XBT
14	29/1730	70°17′ N., 165°02′ W	MWT, XBT
15	29/2340	70°18′ N., 164°41′ W	NAC, NIC, BG, BS, VPT, BC, GC, CAM, XBT
16	30/0700	70°16′ N., 163°58′ W	MWT, XBT
17	30/1100	70°16′ N., 163°55′ W	T, BC, XBT
18	30/1736	70°24′ N., 164°09′ W	NAC, NIC, BG, VPT, T, BC, GC, CAM, XBT
19	30/2316	70°22′ N., 163°16′ W	NAC, NIC, BG, BS, VPT, T, BC, XBT
20	Oct. 1/0656	70°20′ N., 163°24′ W	MWT, XBT
21	1/2346	70°34′ N., 163°16′ W	NAC, NIC, BG, BS, VPT, T, BC, CAM, XBT
22	2/0554	70°20′ N., 168°25′ W	MWT, XBT
23	2/2030	70°23′ N., 162°24′ W	NAC, NIC, BG, BS, VPT, T, CAM, XBT
24	3/0200	70°09′ N., 162°57′ W	NAC, NIC, BG, VPT, T, CAM, XBT
25	3/0625	70°07′ N., 163°14′ W	MWT, XBT
26	3/1842	70°11′ N., 162°52′ W	NAC, NIC, BG, VPT, T, CM, CAM, XBT
27	4/0736	70°11′ N., 163°19′ W	T, BC, PF
28	4/1700	69°59′ N., 163°17′ W	NAC, NIC, BG, VPT, T, BC, CM, CAM, XBT
29	4/2346	70°01′ N., 163°59′ W	NAC, NIC, BG, VPT, BC, GC, CAM, XBT
30	5/0600	69°58′ N., 164°07′ W	MWT, XBT
31	5/1700	69°45′ N., 163°34′ W	NAC, BG, VPT, CM, CAM, XBT
32	6/0710	69°48′ N., 163°49′ W	MWT, XBT
33	6/1000	69°47′ N., 164°30′ W	NAC, NIC, BG, VPT, T, CAM, XBT
34	6/1720	69°52′ N., 165°37′ W	NAC, NIC, BG, VPT, T, BC, CAM, XBT
35	6/2200	69°59′ N., 166°30′ W	NAC, BG, VPT, T, CAM, XBT
36	7/0230	70°08′ N., 167°11′ W	NAC, NIC, BG, VPT, GC, CAM, XBT
37	7/0730	70°07′ N., 167°26′ W	MWT, XBT
38	7/1218	69°49′ N., 166° 29′ W	NAC, BG, GC, CAM, XBT
39	7/1708	69°51′ N., 166°47′ W	NAC, BG, VPT, T, XBT
40	7/2230	70°18′ N., 166°57′ W	NAC, BG, VPT, T, BC, GC, CAM, XBT
41	8/0545	69°57′ N., 167°31′ W	BG, MWT, XBT
42	Oct. 8/1246	70°00′ N., 167°41′ W	NAC, BG, T, GC, CAM, XBT
43	8/1658	70°03′ N., 168°26′ W	NAC, BG, VPT, T, BC, CAM, XBT
44	8/2200	70°11′ N., 168°56′ W	NAC, NIC, BG, BS, VPT, T, BC, GC, CAM, XBT
45	9/0640	69°57′ N., 168°38′ W	MWT, XBT
46	9/1004	69°53′ N., 168°39′ W	BG, T
47	9/1102	69°47′ N., 168°38′ W	BG, T
48	9/1248	70°01′ N., 168°34′ W	NAC, BG, T, BC, CAM, XBT
49	9/1700	69°48′ N., 168°04′ W	NAC, BG, BS, VPT, T, BC, GC, CM, CAM, XBT
50	10/0102	69°38′ N., 167°44′ W	NAC, BG, BS, VPT, T, BC, CM, CAM, XBT
51	10/0622	69°36′ N., 167°36′ W	MWT, PF
52	10/1120	69°30′ N., 167°43′ W	BG, T
53	10/1305	69°24′ N., 167°12′ W	BG, T
54	10/1650	69°24′ N., 167°15′ W	NAC, BG, VPT, T, GC, CM, CAM, XBT
55	10/2256	69°13′ N., 166°52′ W	NAC, BG, VPT, T, BC, GC, CM, CAM, XBT, PF
56	11/0740	69°14′ N., 166°53′ W	MWT, XBT
57	11/1150	69°14′ N., 167°00′ W	BG, T

Station	Date/Time (GMT)	Position	Activities [1]
58	11/1300	69°00' N., 166°54' W	BG, T
59	11/1431	69°04' N., 166°40' W	NAC, BG, BC, CM, CAM, XBT
60	11/2301	68°57' N., 166°25' W	NAC, BG, VPT, T, BC, GC, CM, CAM, XBT
61	12/0555	69°05' N., 166°13' W	MWT, XBT
62	12/1732	69°06' N., 166°02' W	NAC, BG, VPT, T, CAM, XBT
63	12/2115	69°14' N., 165°56' W	NAC, BG, VPT, T, CAM, XBT
64	13/0101	69°24' N., 166°29' W	NAC, BG, VPT, T, BC, GC, CM, CAM, XBT
65	13/0555	69°21' N., 166°45' W	MWT, XBT
66	13/1010	69°24' N., 166°59' W	BG, T
67	13/1205	69°31' N., 166°56' W	BG, T
68	13/1420	69°38' N., 166°48' W	NAC, BG, T, GC, CAM, XBT
69	13/1930	69°50' N., 167°23' W	NAC, BG, VPT, T, BC, XBT
70	14/0535	69°12' N., 167°38' W	MWT, XBT
71	14/1315	69°11' N., 136°28' W	BG, T
72	14/1903	69°19' N., 165°11' W	NAC, BG, VPT, BC, CAM, T, XBT
73	15/0025	69°33' N., 164°37' W	NAC, BG, VPT, BC, CM, T, CAM, XBT
74	15/0523	69°35' N., 164°29' W	MWT
75	15/0930	69°31' N., 164°19' W	BG, T, XBT
76	15/1155	69°35' N., 164°48' W	BG, T
77	15/1315	69°36' N., 165°10' W	NAC, BG, T, BC, CAM, XBT
78	15/1850	69°27' N., 165°38' W	NAC, BG, VPT, T, BC, CAM, XBT
79	16/0130	69°28' N., 164°15' W	BG, T, BC, XBT
80	16/0614	69°27' N., 164°43' W	MWT, XBT
81	16/1000	69°29' N., 164°26' W	BG, T
82	16/1135	69°32' N., 164°18' W	BG, T
83	16/1230	69°26' N., 164°26' W	BG, T
84	16/1400	69°20' N., 164°36' W	NAC, BG, BC, CAM, XBT
85	16/1730	69°13' N., 164°45' W	NAC, BG, VPT, T, BC, XBT
86	Oct. 16/2035	69°05' N., 165°05' W	NAC, BG, VPT, BC, XBT
87	17/0035	69°04' N., 165°36' W	NAC, BG, VPT, T, BC, CAM, XBT
88	17/0717	68°55' N., 166°47' W	MWT
89	17/1300	68°47' N., 167°03' W	BG, T, GC, PC
90	17/1700	68°54' N., 166°40' W	NAC, BG, VPT, T, GC, CM, CAM, XBT
91	17/2315	68°54' N., 167°24' W	NAC, BG, VPT, BC, GC, CAM, XBT
92	18/0533	68°36' N., 167° 41' W	MWT, XBT

[1] Activity code NAC=Nansen bottle cast, NIC=Niskin bottle cast, BG=bottom grab, BS=bird sampling, VPT=vertical plankton tow, T=transmissometer lowering, BC=box core, GC=gravity core, PC=piston core, CM=current meter, CAM=bottom camera, MWT=mid-water trawl, XBT=expendable bathythermograph, PF=precision fathogram, BES=beach survey.

Physical Oceanography of the Eastern Chukchi Sea Off Cape Lisburne—Icy Cape

MERTON C. INGHAM[1] and BRUCE A. RUTLAND[1]

GENERAL DESCRIPTION OF STUDY AREA

Geography

The Chukchi Sea is a small (580,000 km²), shallow (<100 fm) sea lying between the Arctic Ocean and Bering Strait, extending from near Wrangel Island (180) to Point Barrow (156° W), generally bounded on the north by the 100 fm isobath which lies from 300 miles (near Cape Lisburne) to about 30 miles offshore (near Point Barrow). The southeastern portion of this sea lies over the continental shelf off Alaska's north coast adjacent to hilly lowlands of varying width (nonexistent near Cape Lisburne) which separates the sea from the Brooks Range roughly paralleling the coastline (Hunkins and Kaplan, 1966). The portion of the eastern Chukchi Sea studied during the WEBSEC-70 cruise lay off Cape Lisburne-Icy Cape in shallow water (<50 m), forming a triangular area about 100 miles offshore at its farthest point (figs. 1 and 2).

Ice Cover

The area of open water in the eastern Chukchi Sea varies seasonally with the position of the polar icepack, which depends on the wind field, and the extent of winter ice, which depends on insolation, air temperature, and wind speed. Ice conditions in the Chukchi Sea have been summarized as follows in the Oceanographic Atlas of the Polar Seas—Part II The Arctic. (U.S. Navy Hydrographic Office, 1958):

"Chukchi and Beaufort Seas—The waters of the Chukchi and Beaufort Seas are dominated most of the year by winter ice and polar pack ice which includes heavy drift ice from the Arctic Ocean. Of lesser importance is the fast ice which covers the bays and fringes the shores of northern Alaska and Siberia for at least 8 months.

"Generally August and September are the months with the least ice. During this period the northwest coast of Alaska should be free of fast ice northward to Point Barrow and practically ice free from Point Barrow eastward to Herschel Island. However, the heavy polar pack is never far off the coast between Point Barrow and Herschel Island and can advance onto the shore at any time. Westward of Point Barrow the pack ice usually lies about 10 miles offshore at Icy Cape; beyond this point the edge of the pack swings northwestward toward Ostrov Geral'd and Wrangel Island. The ice edge then trends southwestward, approaching the Siberian coast at about the vicinity of Mys Shmidta.

"The existence of an open coastal waterway in the Chukchi-Beaufort Sea sector is strongly dependent upon favorable winds. Easterly and southerly winds hold the pack off tne coast, whereas northerly and westerly winds force the floes against the shore. Even when the main body of the ice recedes from the coast, drifting marginal floes and bands of fast ice occur in the inshore waters.

"The heavy pack ice begins to close in on the coast after about 10 September, and young ice forms along the margins of the drift ice and in any open water that may exist between the pack and the coast by mid-September.

"The north-setting current in Bering Strait usually keeps the Alaskan coast ice-free throughout September as far north as Cape Lisburne, but before the end of the month the Arctic ice may be expected to begin its expansion and southward movement. Before the

[1] U.S. Coast Guard Oceanographic Unit, Bldg. 159-E, Navy Yard Annex, Washington, D.C. 20390.

first of October the drift ice, which earlier had been along the Siberian shore, may begin to advance around Mys Dezhneva into the western side of Bering Strait.

"Ice formation and growth proceed rapidly in early October, and shipping is usually not feasible north of Bering Strait after about 10 October. Prevailing north and northeast winds pile large accumulations of flocs against the Siberian shore.

"Between Point Barrow and Icy Cape drift ice occasionally recedes from the coast, and young ice which forms in the open water is piled up in heavy masses along the shore when the drift ice returns. Kotzebue Sound and Bering Strait are closed during middle and late October by fast ice. By late October or early November, ice closes North Sound. As the formation of ice continues toward midwinter, the ice limit gradually progresses southward until at its maximum, navigation north of the Pribilof Islands becomes impossible for ships other than icebreakers."

Climate

An estimate of the annual variation of meteorological factors directly influencing sea-air interaction in the eastern Chukchi Sea can be obtained from atlases of average weather conditions and from accumulated weather station observations. The paucity of weather stations and reporting ships in this geographical area make such an estimate inaccurate and imprecise at best.

Mean monthly values of surface wind (vector average) and temperature from volume VIII of the Marine Climatic Atlas of the World (U.S. Naval Weather Service Command, 1969) reveal a relatively small range of seasonal variation in the eastern Chukchi Sea. Observations taken over periods of 9 and 12 years from Point Hope and Point Barrow respectively (table 1), showed that winds were from the NE-NNE at both coastal stations in all months but January at Point Barrow (WNW) and July and August at Point Hope (SE and WNW). The average wind speed at Point Barrow ($<2\frac{1}{2}$–5 kts) was lower than at Point Hope ($<2\frac{1}{2}$–10 kts), but the patterns of variation were approximately the same at the two stations: lower speeds in January-February and June-August. The monthly percentage frequency of winds of gale force (≥ 34 kts, table 2) was always less than 5 percent at Point Barrow and exceeded 5 percent at Point Hope only during November and December. Conversely, the monthly percentage frequency of light or gentle winds (≤ 10 kts, table 2) was lowest at both stations during October-December, highest at Point Hope during May-June, and highest at Point Barrow during January-February and June.

Table 1.—Monthly average wind velocity (vector average) and air temperature for Point Hope and Point Barrow, Alaska. From Marine Climatic Atlas of the World—Vol. VIII (U.S. Naval Weather Service Command, 1969).

Month	Wind				Air Temp. (°F)	
	Point Hope		Point Barrow		Point Hope	Point Barrow
Jan.	NNE	2½-5	WNW	<2½	−10	−17
Feb.	NNE	5-10	NE	<2½	− 8	−20
Mar.	NNE	5-10	NE	2½-5	− 5	−15
Apr.	NNE	5-10	NE	2½-5	+ 6	0
May	NNE	2½-5	ENE	5-10	+23	+20
June	NNE	<2½	ENE	<2½	+36	+32
July	SE	<2½	E	<2½	+42	+40
Aug.	WNW	<2½	NE	<2½	+42	+40
Sept.	NNE	2½-5	ENE	2½-5	+34	+30
Oct.	NE	5-10	NE	2½-5	+23	+14
Nov.	NE	2½-5	NE	2½-5	+12	0
Dec.	NE	5-10	NE	2½-5	− 3	−12

Table 2.—Monthly average percent frequency of observed winds equal to or greater than 34 kts and equal to or less than 10 kts at Point Hope and Point Barrow. From Marine Climatic Atlas of the World—Vol. VIII. (U.S. Naval Weather Service Command, 1969).

Month	Percent frequency Winds ≥34 kts.		Percent frequency Winds ≤10 kts.	
	Point Hope	Point Barrow	Point Hope	Point Barrow
Jan.	<5	<5	37	57
Feb.	<5	<5	35	54
Mar.	<5	<5	33	>50
Apr.	<5	<5	40	>50
May	<5	<5	>50	51
June	<5	<5	51	59
July	<5	<5	40	50
Aug.	<5	<5	35	50
Sept.	<5	<5	35	50
Oct	<5	<5	>30	41
Nov.	10	<5	29	47
Dec.	>5	<5	32	>50

Prevailing winds at Point Barrow and off Icy Cape (tables 3 and 4) showed a pattern

of variation stronger than that revealed by the vector average winds (table 1), as is to be expected. The most prevalent winds in all months in both areas are E-NE except for SW winds during July off Icy Cape. Seasonal variation in the wind field is more pronounced in the third and fourth most prevalent directions (octants) where W-SW winds appear more frequently during the summer months. This pattern was more pronounced at Point Barrow than off Icy Cape.

Table 3.—Mean monthly percent frequency of observed winds in the four most prevalent octants at Point Barrow. Values from charts in the Marine Climatic Atlas of the World—Vol. VI Arctic Ocean (U.S. Navy, 1963).

Month	Most prevalent octant	Second	Third	Fourth
Jan.	E 22	NE 19	SW 11	N 10
Feb.	E 21	NE 20	W 17	SW 10
Mar.	NE 31	E 18	N 10	SW 9
Apr.	NE 27	E 23	N 11	S 9
May	NE 35	E 29	N 7	SE 6
June	E 28	NE 24	SW 13	W 10
July	NE 21	E 20	SW 16	W 10
Aug.	E 23	NE 21	SW 12	W 11
Sept.	E 26	NE 23	SE 10	N 10
Oct.	NE 27	E 23	SE 13	S 12
Nov.	NE 33	E 21	S 10	SE 9
Dec.	NE 30	E 18	SW 9	W 9

Table 4.—Mean monthly percent frequency of observed winds in the four most prevalent octants off Icy Cape (shipboard observations). Values from charts in the Marine Climatic Atlas of the World—Vol. VI Arctic Ocean (U.S. Navy, 1963).

Month	Most prevalent octant	Second	Third	Fourth
Jan.	---------			
Feb.	---------			
Mar.	---------			
Apr.	---------			
May	E 36	NE 28	SE 8	W 7
June	E 28	W 12	SE 11	S 10
July	SW 21	NE 20	N 15	E 13
Aug.	NE 22	E 20	SW 11	W 11
Sept.	N 20	E 18	NE 16	NW 9
Oct.	NE 54	E 20	N 10	SE 6
Nov.	NE 58	E 12	N 8	W 6
Dec.	NE 59	E 22	SW 7	N 6

Mean monthly surface air temperature (table 1) varied seasonally with the highest temperature at Point Hope and Point Barrow occurring in July and August. The seasonal low temperature at Point Barrow occurred in February, 1 month later than at Point Hope. The mean temperature was lower at Point Barrow than at Point Hope during all months by an amount ranging from 2 to 12 F° (1.1 to 6.7 C°).

Oceanography

Some past oceanographic investigations of the eastern Chukchi Sea have included a few observations in the Cape Lisburne-Icy Cape area, but no comprehensive survey had been attempted there prior to WEBSEC-70. However, the results of past cruises are detailed enough to yield a general description of the eastern Chukchi Sea during the summer and early fall.

Sauer, et al. (1954), described water masses found in the eastern Chukchi Sea (65–73° N, 164–169° W) in the summer of 1949. The temperature and salinity data used for classification of the water masses were obtained by bathythermograph and titration of water samples, both means yielding data of lower precision and accuracy than is common in more recent investigations. The water masses they identified in the vicinity of Cape Lisburne-Icy Cape were Alaskan Coastal Water (approx. >6.6° C, <30.5‰) occupying the entire water column near the continent, and Intermediate Water (approx. 4–6.3° C., 30.6–32.2‰) found near bottom near the continent and at the surface farther north. As the authors pointed out, the water mass classifications may be valid in a particular area for the summer season only.

Water masses were described by Aagaard (1964) based on temperature and salinity data collected in the eastern Chukchi Sea in October 1962. He found "Alaskan coastal water" (>1° C, <31‰) to occupy the surface layer near the continent and a layer of "warm subsurface water" (>2.0° C, 31.5–32.4‰) beneath it. Both of these masses were found as far north as Point Hope, but northerly winds apparently blocked the flow of Alaskan coastal water into the Cape Lisburne-Icy Cape area. Near the bottom in the central and northeastern Chukchi Sea, he found a water mass characterized by salinity greater than 32.9‰, temperature greater than 1° C, and low concentrations of dissolved oxygen (down to 26 percent saturation). With the data available to

him, Aagaard was unable to isolate the source of this water mass but named the Bering Sea, East Siberian Sea, and northern Chukchi Sea as possibilities.

Fleming and Heggarty (1966) described water properties found in the eastern Chukchi Sea on two summer cruises (2 August–1 September 1959 and 26 July–28 August 1960) but did not define water masses based on the observed properties. They found warmer, less saline water near the Alaskan coast extending northward, more or less parallel to the coastline, as far as Icy Cape. In the Cape Lisburne-Icy Cape area nearer the shore, they found a southwestward surface intrusion of water which was warmer and more saline (7°-10° C, >32‰) than that generally found throughout the area. They offered no suggestion regarding a source of the intruded water. Distributions of temperature and salinity farther offshore imply the presence of a clockwise eddy, suggesting the possibility that the anomalous intrusion may have been the residue of a former eddy trapped downstream from Cape Lisburne.

Kinney, Burrell, et al. (1970), described four distinct water masses present in the Bering Strait in July–August 1968. Their description was based on an analysis of four groups of factors: nutrients, organics, C/N and PM (carbon/nitrogen and particulate matter), and physical variables (temperature, salinity, and density). The identified masses were characterized as follows:

1. deep water in the center of the strait and surface water on the western side with high nutrients, low organics, high salinity, and low temperature,
2. surface water in the central strait with partially depleted nutrients, high organics, and varying temperature and salinity,
3. surface water in the eastern strait with low nutrients, low organics, low salinity, and high temperature, and
4. deep water in the eastern strait with low nutrients and high organics.

Because the waters of the Bering Strait flow northward into the Chukchi Sea, these four water masses, particularly those of the eastern and central portions, are important in any study of the Cape Lisburne-Icy Cape area.

A general description of the circulation in the eastern Chukchi Sea can be constructed from several reports of investigations in the area and atlas portrayals of average surface currents. In a few of these publications the current portrayals are based on direct measurements, but most of them are based on inference from the distribution of water properties.

The U.S. Navy Hydrographic Office Oceanographic Atlas of the Polar Seas—Part II Arctic (USNHO, 1958) shows a pattern of surface currents (fig. 4) flowing northward into the Chukchi Sea from the Bering Strait to the vicinity of the Point Hope-Cape Lisburne promontory, then northeastward through the Cape Lisburne-Icy Cape area, with speeds of 0.5 to 1.7 knots. This portrayal was based on records of vessel drift and dynamic considerations, the latter being of little value in the shallow Chukchi Sea.

During a joint United States-Canadian expedition to Arctic waters in the summer of 1949 (Lesser and Pickard, 1950), 28 direct measurements of currents were made in 15 locations in the eastern Chukchi Sea (four surface and two bottom measurements in the Cape Lisburne-Icy Cape area). Surface measurements were made with a drift pole and near-bottom measurements were made with an Ekman meter. Surface currents ranged from 0.0 to 0.5 knots in essentially random directions, except for two measurements made near Point Hope and near Cape Lisburne which showed currents diverging from the headlands (NW and WNW) at 2.0 and 1.0 knots, respectively. Near bottom (160 cm above the bottom) currents in the same area (four measurements) were found to be generally northward, paralleling local isobaths at speeds ranging from 0.2 to 0.5 knots.

The most extensive program of current measurements in the eastern Chukchi Sea to date was conducted by the University of Washington in July–August 1960 as part of a study of the environment of the Cape Thompson region (Fleming and Heggarty, 1966). Current meter observations were made at 161 stations, 21 of which were in the Cape Lisburne-Icy Cape area. Drift cards and drogue buoys also were used to measure surface currents, but only south of Cape Lisburne. The measurements revealed a general circulation pattern (fig. 5) involving a northward flow from the

Bering Strait which approximately paralleled local isobaths, converged on promontories and curved into a clockwise eddy northeast of Cape Lisburne. The distributions of temperature and salinity supported this pattern with isotherms and isohalines generally paralleling the isobaths and forming an eddy pattern northeast of Cape Lisburne.

There have been no extensive programs of current measurement in the eastern Chukchi Sea during the fall months. Aagaard (1964) has reported the results of a cruise in this area during October 1962 but there were no direct measurements of current performed and his description of circulation was based entirely on inference from the distributions of water properties. He described a two-layer system involving "Alaskan coastal water" in the surface layer and "warm subsurface water" beneath it. The "Alaskan coastal water" did not flow northeastward from Cape Lisburne as expected but turned to the northwest instead, apparently because of prevailing northeasterly winds in the Cape Lisburne-Icy Cape area. The "warm subsurface water," however, apparently was not influenced by the wind stress and turned to flow northeastward beyond Cape Lisburne.

There are no general descriptions of circulation during the winter months in the eastern Chukchi Sea. Coachman and Tripp (1970) have reported measurements obtained over a period of 4 days, 21–25 March 1968, with a recording current meter suspended 15 m beneath an ice floe drifting about 190 km (114 nm) NNE of Bering Strait (approximately 140 nm SW of Cape Lisburne). Their results indicated that the northward flow from the Bering Strait that has been frequently measured in summer months also is present in winter.

RESULTS OF WEBSEC–70

Data Collection and Processing

WEBSEC–70 was conducted from the USCGC GLACIER (WAGB-4) in the eastern Chukchi Sea during 23 September–18 October 1970. Eighty-five stations were occupied in the vicinity of Cape Lisburne-Icy Cape in a gradually diminishing area of open water between the polar ice pack and the northern Alaskan coast (figs. 1 and 2). Physical and chemical oceanographic data were collected at these stations from 47 Nansen bottle casts, 136 expendable bathythermograph (XBT) drops, and 28 current meter lowerings.

Temperature

Water temperature data were obtained by use of paired reversing thermometers attached to Nansen bottles and by XBTs calibrated with bucket thermometer readings.

Salinity

Water samples were drawn from Teflon-lined Nansen bottles for salinity determinations conducted on board with inductive salinometers. The salinometers were calibrated with standard (Copenhagen) water at least once per 30 samples. Conductivity values obtained were converted to salinity values by use of the International Oceanographic Tables published jointly by UNESCO and the National Institute of Oceanography of Great Britain (UNESCO, 1966).

Dissolved Oxygen Concentration

Water samples were drawn from Teflon-lined Nansen bottles for shipboard analysis of dissolved oxygen by means of a modified Winkler titration (Strickland and Parsons, 1968). Values of percent saturation were computed utilizing a computer program based on tables of oxygen saturation developed by Green and Carritt (1967).

Dissolved Nutrients

Techniques described in the manual of Strickland and Parsons (1968) were used in the determination of nutrients. Molybdate complexes of phosphate and silicate were reduced to form colored complexes. Nitrate was first reduced to nitrite using a cadmium-copper column, and then converted to a highly colored azo dye. A Beckman DU-2 spectrophotometer was employed in measuring the light transmittance of the treated samples. The resulting extinction values were converted to concentrations, in microgram-atoms/liter, taking into account the salt effect.

Sampling Depth

The Nansen casts were all too shallow to employ effectively unprotected reversing thermometers to obtain measurements of sampling depths. Meter wheel readings and wire angle

measurements were used to compute estimates of sampling depths. Because all of the casts were made to depths of less than 50 meters under conditions of low wire angle, no significant errors are thought to exist in the computed estimates.

Currents

Direct measurements of currents were made on 14 stations at two depths from the vessel at anchor. A Hydroproducts model 502 recording current meter (CGOU) was lowered to 10 m depth and allowed to run for periods ranging from 1 to 35 hours (about 1½ hours on most stations). A Geodyne model 102 recording current meter (USGS) was lowered to within 1.5-2 m of the bottom on most of the same stations for simultaneous measurement of near-bottom currents.

Strip charts from the Hydroproducts meter were digitized by hand, yielding data points at 3½-minute intervals. Calibration corrections were applied to the speed data, and corrections for magnetic variation were applied to the direction record. The data were then processed to yield means and standard deviations of speed and direction, progressive vector diagrams, vector histograms, and vector averages.

Photographic records from the Geodyne current meter were processed by machine, yielding speed and velocity information at 1-minute intervals. These values then were reprocessed by computer to obtain 15-minute, 1-hour, and overall vector sums. Vector values were corrected for magnetic variation before progressive vector diagrams were plotted.

Meteorological Observations

Surface meteorological observations were made at 6-hour intervals and on each station. Upper air observations were made daily.

Ice Observations

Observations of ice cover and pack edge location were made visually and by radar from the vessel routinely and from helicopter reconnaissance flights when necessary.

Quality Control

Initial quality control of all physical and chemical oceanographic data was performed on board GLACIER, and final control was conducted at the Coast Guard Oceanographic Unit. All of the oceanographic data were submitted to the U.S. National Oceanographic Data Center (NODC) for archiving and further processing. NODC listings of the processed data have been included in this report (appendix A).

Surface Properties and Air-Sea Interaction

Ice conditions encountered during WEBSEC-70 (fig. 6) were much like those described as average for September–October (U.S. Navy Hydrographic Office, 1958). Both the advance of the polar ice pack on the coastline and the freezing of winter ice were approximately "on schedule." Oceanographic stations were generally occupied in the relatively ice-free water between the main pack edge and the coast (10 fm isobath), except for occasional stations and stations 9 through 23 which were occupied near the pack edge by design (figs. 2 and 6). Station 21 was located about 10 nautical miles inside the pack edge, the deepest penetration of the cruise.

The proximity of the ice pack influenced water properties at the sea surface and, to a lesser extent, in the upper 10 meters. Melting along the pack edge lowered temperature and salinity of the adjacent water to values generally less than 1° C and 31 ppt (figs. 7, 8, 10, 11). The concentration of dissolved oxygen in the surface layer was higher in the vicinity of the ice pack (figs. 13, 14), but this only reflects the greater solubility of oxygen in colder water, as is evident from the lack of similar patterns in the distribution of percent saturation of dissolved oxygen (figs. 16, 17). Nutrient values in the northern sector of the survey (figs. 19, 20, 22, 23, 25, 26, 28, 29) also appeared to be influenced by melt water from the adjacent ice pack. Dilution of surface values by the melt water apparently resulted in low concentrations; stations near the ice pack off Icy Cape showed the lowest surface nutrient values encountered.

The variation of weather conditions during the cruise period strongly influenced surface water properties. Air temperature (fig. 31) remained nearly constant during the early portion of the cruise (stations 8–30, 25 September–5 October), then generally decreased for the remainder of the cruise (stations 30–87, 5–17 October). An increase in air temperature

noted during 17–18 October (stations 89–92) probably was the result of moving to the area west of Cape Lisburne, instead of a change in the weather patterns. Sea surface temperature (fig. 7) followed a similar pattern of variation: nearly constant during the early part of the cruise (stations 8–30), with some variation resulting from varying proximity to the edge of the ice pack, and decreasing for the remainder of the cruise (stations 30–87).

An area of low sea surface temperature (<0° C) near shore near Cape Lisburne (stations 73–87, fig. 7) was the result of strong cooling by the overlying cold air mass (<−10° C). Ice was rapidly freezing on the sea surface as these stations were occupied, in response to steadily decreasing air temperature.

Variations in the surface wind field during the cruise period (fig. 32) included two periods of relative calm (most observations <10 kts), which occurred during the early and middle portions (stations 8–30, 25 September–5 October, and stations 45–60, 9–11 October). These were interspersed with two periods of strong winds (up to 35 kts) from the NNE-ENE octant (stations 30–45, 5–9 October, and stations 60–85, 11–16 October). Time variation of sea surface temperature showed a tendency toward higher temperatures or a period of slow decrease corresponding with the two windy periods, probably because of mixing of warmer, more saline, subsurface water with the surface layer. In addition, the surface temperature of the air mass involved in the first windy period was higher than that observed preceding or following the periods.

Variations in meteorological conditions and their effect on the distributions of surface and near-surface water properties were large enough to render the observed distributions asynoptic over the full period of the cruise. Consequently, the contoured sections of the physical and chemical properties of the water must be viewed with their asynoptic character in mind, and inferences of flow based on these sections can be considered valid for only short periods of the cruise.

Water Masses

The temperature and salinity values observed in the Cape Lisburne-Icy Cape area during WEBSEC–70 did not correspond closely with water mass properties defined by Saur et al. (1954) and Aagaard (1964) (figs. 33, 34). As might be expected, the WEBSEC–70 values were closer to Aagaard's fall values than Saur's summer values. The lack of agreement between the observed values and previously defined water masses is not surprising, in light of the wide time-dependent variation of the properties of the shallow water of the Chukchi Sea and the inflow from the Bering Strait.

The surface water sampled in the Cape Lisburne-Icy Cape area (designated by dots in fig. 35) appeared to be a cooler, more saline variety of the "Alaskan coastal water" defined by Aagaard (1964). Underlying the modified Alaskan coastal water often was found water with T–S characteristics corresponding with those of the "warm subsurface water" defined by Aagaard (1964). Occasionally the warm subsurface water was found at the sea surface. Many of the T–S points fell between the two water masses defined by Aagaard, which merely exemplifies the need to adjust the boundaries of the definitions.

Rather than inventing new water mass definitions or modifying existing ones to fit the observed properties, it may be simpler to consider the physical processes and water masses at the periphery of the T–S distribution which influence the properties of the main volume of water entering the eastern Chukchi Sea (fig. 36). Merely to facilitate discussion, the inflowing water mass will be called Eastern Chukchi Sea Fall Influx (ECSFI).

Alaskan coastal runoff, both as a component of ECSFI and as an addition to it north of the Bering Strait, tends to produce higher temperatures and lower salinities in the surface layer. The volume of runoff, and accordingly its influence on water properties, varies seasonally, and from year to year. Because freezing conditions were prevalent during WEBSEC–70, the effects of runoff on the water properties observed in the Cape Lisburne-Icy Cape area were greatly reduced, yielding cooler and more saline water than normally found during the summer and fall months.

Melting of sea ice will produce a surface layer of cooler (as low as −1.8° C) and less saline (<30 ppt.) water. A layer of water whose properties were modified in this manner

was found in the vicinity of the edge of the polar ice pack during the early portion of WEBSEC–70 (figs. 7, 8, 10, 11, 37, 38). The layer, which was easily distinguished from water beneath and adjacent to it, was quite limited in its vertical and horizontal extent (about 10 m or less thick and a few miles from the pack edge), thus representing a small volume relative to the total volume studied during the cruise.

Freezing of sea ice will produce a change in the entire water column, making it colder (down to about −1.8° C) and more saline (>31 ppt here). These changes occur stepwise, in temperature first, then in salinity when the freezing point is reached. Many of the stations occupied during the last portion of the cruise (stations 72–87) showed the effects of rapid cooling and freezing (figs. 7, 8, 9). Temperature-salinity plots of these stations (fig. 35) are virtually points, indicating the nearly isothermal and isohaline conditions in the water column produced by convective overturn resulting from the strong cooling and freezing of sea ice.

Inclusion of water from near bottom in the central Bering Strait would decrease the temperature and increase the salinity of the water column (fig. 36). The effects of this water category were found near bottom on stations in the northwestern corner and along the northern boundary of the WEBSEC–70 area of investigation. Stations in deeper portions of the Chukchi Sea farther north (inaccessible during WEBSEC–70) probably would reveal this water category to be a common component of the water column.

Water properties along the western edge of the area of investigation (stations 44–60, section B–B′), which would be "upstream" in a current pattern such as that described by previous investigators, varied significantly in their horizontal and vertical distributions (figs. 39–45). Maximum temperatures (>3° C) at all depths were found in the center of the section (stations 49 and 50), where the water column was nearly isothermal. Minimum temperatures (<1° C) in the section were found near the surface on station 44 (near the ice pack) and near the bottom on station 48.

The distribution of salinity along the section (fig. 40) generally did not parallel the distribution of temperature. Salinity changed very little northward from Cape Lisburne (station 60) until beyond the midpoint (station 49), and the water column was nearly isohaline in the section between stations 49 and 60. North of station 49 salinity increased at all levels, but most rapidly near bottom, where a maximum of 32.66 ppt was found on station 48.

The combination of temperature and salinity values observed near bottom on the stations at the northern end of the section (stations 44, 48, and 49) and along the northern boundary of the study area closely correspond with those observed below 20 m in the central Bering Strait (fig. 33) during a cruise of the USCGC NORTHWIND in October 1962 (U.S. Coast Guard, 1964). In addition, the distributions of dissolved nutrients in the near bottom water on this section (figs. 42–45) showed higher values for each nutrient sampled. The higher nutrient concentrations add to the hypothesis that the near bottom water on stations 44, 48, and 49 came from the central Bering Strait. All these water properties correspond well with the characteristics of a Bering Strait water mass described by Kinney, Burrell, et al. (1970), which was found at the surface in the western strait and at the bottom in the center of the strait, and was characterized by high nutrients, low organics, high salinity, and low temperature. This mass also was thought by Kinney, Burrell, et al. to make up the bottom water of the central and western Chukchi Sea.

The possibility that the near-bottom water found along the northern edge of the WEBSEC–70 area may have come from the Arctic Basin instead of the central Bering Strait is negated by the following observations: (1) The WEBSEC–70 near-bottom water was warmer by 2–4° C than Arctic Basin water (Coachman and Barnes, 1961) of the same salinity range (31.8–32.6‰) and density range (σ_t 25.5–26.5). (2) The WEBSEC–70 near-bottom water contained less dissolved oxygen (about 1.5–2.0 ml/l less) and more silicate (about 20–30 μg-at/l more) than Arctic Basin water (Kinney, Arhelger, and Burrell, 1970) of the same density range. (3) The WEBSEC–70 near-bottom water contained substantially less oxygen, more silicate, more phosphate, more nitrate, and was warmer than Arctic

Basin water (Kinney, Arhelger, and Burrell, 1970) in the same depth range (35–50 m).

Water near the bottom in the East Siberian Sea was found by Codispoti and Richards (1963) to contain concentrations of phosphate and silicate which are quite similar to those found near the bottom in the northern edge of the WEBSEC–70 area. However, the temperature, salinity, and concentration of nitrate were unlike those found in the WEBSEC–70 area. These dissimilarities and the lack of evidence of flow from the East Siberian Sea to the eastern Chukchi Sea rule out the East Siberian Sea as a source of the WEBSEC–70 near-bottom water.

Horizontal distributions of dissolved nutrients on the sea surface and 10-m surface (figs. 19, 20, 22, 23, 25, 26, 28, 29) showed a general northwestward decrease in concentrations of all those measured. Such a decrease would be expected if the flow were northwestward and photosynthesis were taking place at these levels. However, Fleming and Heggarty (1966) estimated the residence time for water in the southeastern Chukchi Sea to be only about 10 days, scarcely enough time to develop the gradients observed under fall light conditions. The residence time may be substantially longer than the estimate, perhaps because of the formation of eddies northeast of Cape Lisburne and the reduction of flow through the area by strong northeasterly winds.

An interesting feature visible on nearly all charts of horizontal distributions of water properties was an area of vertically well mixed cold water with relatively high nutrient content, found extending westward from Point Lay. Steep horizontal gradients were found in the concentrations of phosphate and nitrate at all levels. The high nutrient load of this water probably was the result of incorporation of nutrients from the bottom sediments into the overlying water and vertical mixing caused by convective overturn and wind mixing, since the stations involved were occupied late in the cruise during a period of strong cooling and rapid freezing.

The distribution of oxygen in the area of study showed little variation, particularly in terms of percent saturation (figs. 16–18). The slightly lower oxygen values observed near bottom along the northern boundary of the area of study are characteristic of water from near bottom in the central Bering Strait. Convective processes produced concentrations very near saturation in the rest of the water column along the northern boundary and in the rest of the area of study.

Currents—Direct Measurement

Current meter records obtained during WEBSEC–70, which have been digitized and summarized (figs. 46–74), revealed a wide variation in magnitude and direction. Tidal variations were not evident in the 30-hour records (15-minute average progressive vector plots, figs. 60 and 74) from station 8. This is not surprising because the currents associated with the mixed semidiurnal tides in the eastern Chukchi Sea are relatively weak. Fleming and Heggarty (1966) reported measurements of tidal currents of less than 0.1 kt just south of Point Hope.

During the 31 hours of current measurement at station 8, the motion of the vessel swinging at anchor introduced variation into the velocity records. A log of the vessel's heading, recorded at 15-minute intervals for 13 hours, showed that the vessel moved through an arc of 150° (210–360° T) during the full period, and through an average arc of 15.2° in 15 minutes. Assuming uniform motion during the 15-minute period, a swing of 15.2° would produce a recorded velocity of 0.09 kt at right angles to the vessel's heading. The maximum swing observed during any 15-minute period was 50°, which similarly would yield a recorded velocity of 0.29 kt. The vector average near-bottom current speed during the 31-hour period was only 0.08 kt, which is only slightly larger than the average velocity imparted by the ship's swinging at anchor. The spurious velocity record due to the vessel's motion thus renders short-term averages or instantaneous velocities in the record nearly useless. The strip chart from the 10-m current meter shows variation in direction (assumedly due to swinging at anchor) with no obvious general period. Only the trends revealed by progressive diagrams or long term vector averages can be considered as significant under these circumstances.

Currents at the 10-meter depth (fig. 75) generally fell within the same quadrant and often the same octant as the wind velocity (fig.

32) on the same or preceding stations, except at stations 28, 29, 54, and 55, where winds were weak and variable. During periods of strong northeasterly winds the flow at 10 m (and less) was generally before the wind, southwestward out of the Cape Lisburne-Icy Cape area, opposite to the general flow expected. Whenever the northeasterly winds subsided, the near-surface currents apparently returned to a pattern of flow into the area, toward the northeast. Evidence for this was observed in the current measurements made of stations 54 and 55, during a period of weak and variable winds, and station 64 nearby, during a period of strong northeasterly winds (fig. 75); the former two stations showed northeastward currents and the latter station showed southwestward current.

In the nearshore area between Point Lay and Icy Cape the 10-m currents were weak and widely variable. Because of the influence of tidal currents, vessel's motion, and variable winds, little significance can be given to the current measurements, except that they lacked the orderly alongshore flow expected.

Near bottom currents (vector averages) varied from the 10-m currents both in direction (up to 140° either to the right or left) and speed (up to 0.38 kt). Excluding the observations on stations 60 and 90 near Cape Lisburne and station 26 near Icy Cape, however, the near bottom and 10-m currents fell at least in the same quadrant on the remaining 8 stations and within the same octant on 6 of the 8. Near bottom currents entering the area of study were found only on stations 54 and 55, indicating that they were influenced by the northeasterly winds, as was the case for the 10-m currents.

The difference in direction (figs. 60 and 74) between currents at 10 m and near bottom was pronounced during the entire period of measurement (30 hours) on station 8. During the first 5 hours both meters were deployed, the directions differed by about 90°. During the next 16 hours the directions differed by 90–180°. During the last 10 hours the directions differed generally by less than 45° and at times were nearly coincident. The significant changes in direction which occurred in both records did not coincide in time, occurring at the 6-hour mark at 10 m and at the 22-hour mark near bottom. Only 2 of 17 expendable bathythermograph traces obtained at about 2-hour intervals showed evidence of stratification.

Inference from Distributions of Water Properties

The apparent asynopticity of observations over the full cruise period makes it fruitless to attempt extensive inference of flow patterns from the distributions of water properties. The general absence of the parallelism between property isopleths and isobaths, as had been found by previous investigators (Aagaard, 1964, and Fleming and Heggarty, 1966), clearly showed that a regime of orderly alongshore flow did not exist during WEBSEC–70.

SUMMARY OF CONCLUSIONS

1. Pronounced changes in wind velocity and air temperature during the 23-day sampling period produced measurable changes in the distributions of water properties, rendering the oceanographic data collected decidedly asynoptic.

2. Distributions of temperature, salinity, dissolved oxygen, and nutrients showed the influences of Alaskan coastal runoff, melting of sea ice, freezing of sea ice, and bottom water from the central Bering Strait.

3. Distributions of dissolved nutrients showed horizontal gradients which may have been the result of photosynthetic activity in the upper 10 m of moving water. However, if this was the cause of the observed gradients, the residence time of water in this area of the Chukchi Sea must have been longer than the 10 days estimated by Fleming and Heggarty (1966).

4. Currents at 10 m and near bottom were found to be strongly influenced by the wind. Significant northeastward currents (to be expected from average charts) entering the area of investigation were found only on two stations, during a period of weak and variable winds. Currents ranged from southwestward to northwestward during periods of strong northeasterly winds.

5. Currents near shore (15 miles off) between Cape Lisburne and Icy Cape were generally weak and variable, suggesting the possibility of an eddy or pocket of slack water northeast of Cape Lisburne.

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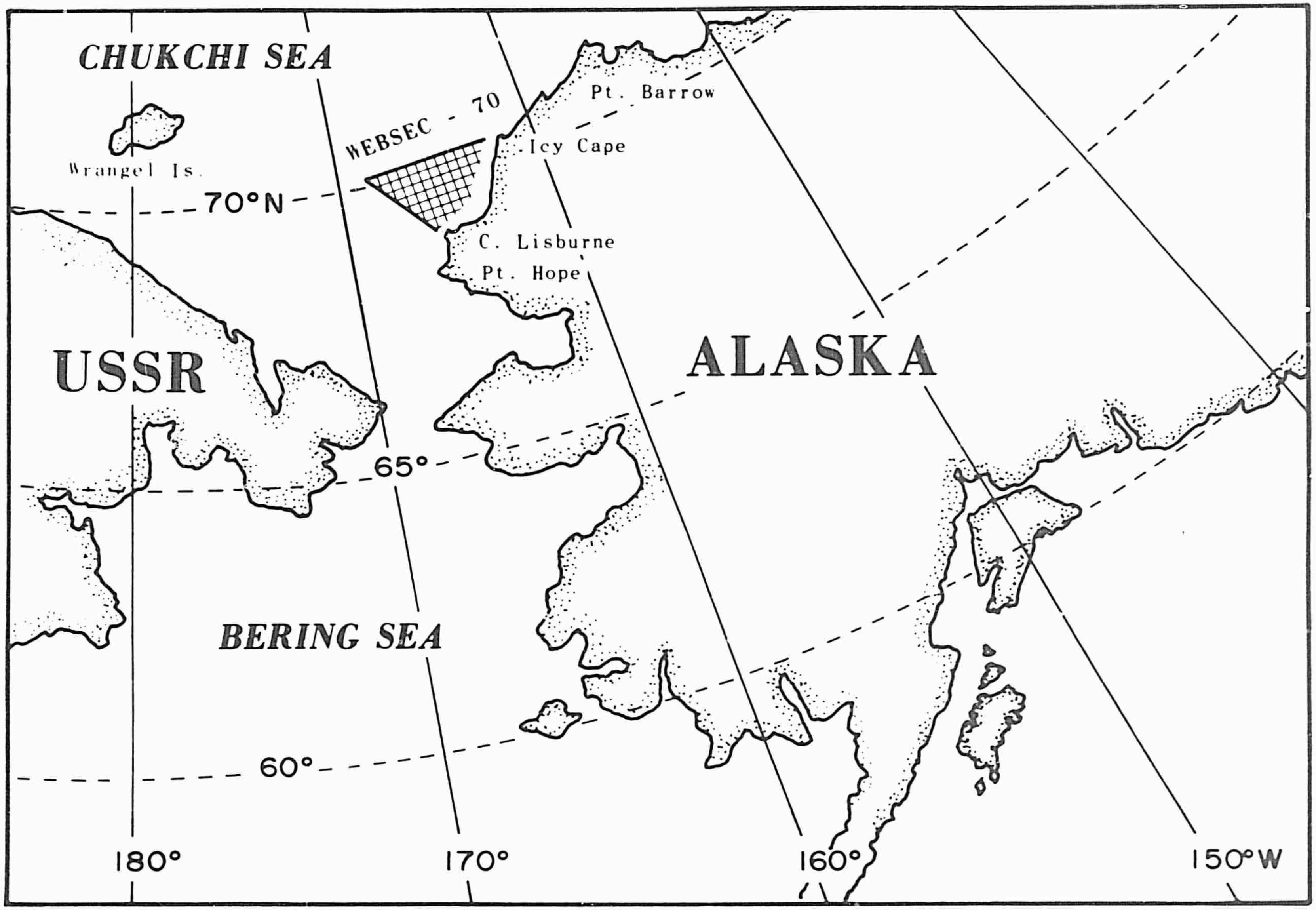


Figure 1.—Location of area studied during WEBSEC-70, 25 September–17 October 1970.

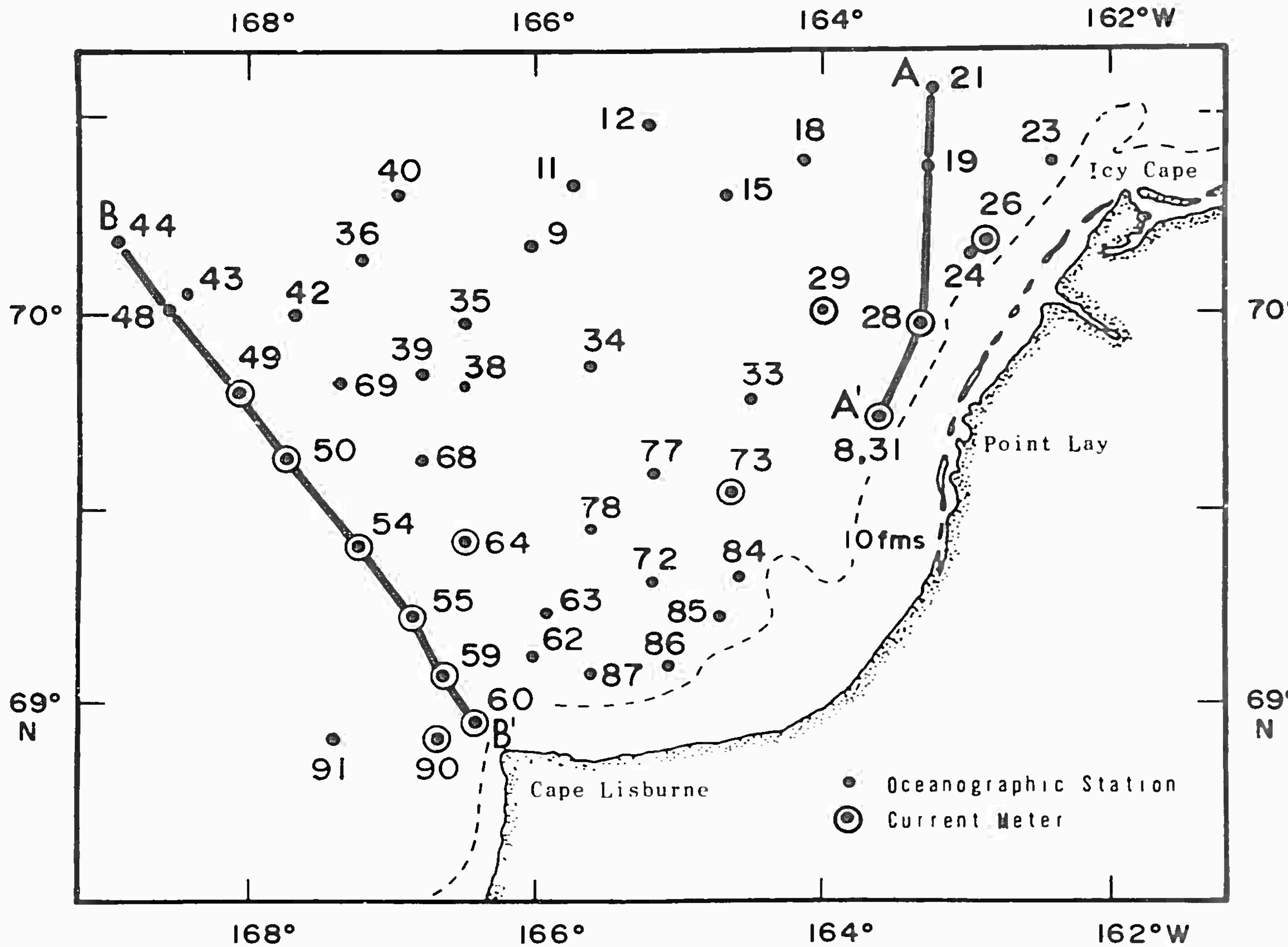


Figure 2.—Location of oceanographic (water sampling) stations and sections, WEBSEC-70, 25 September–17 October 1970.

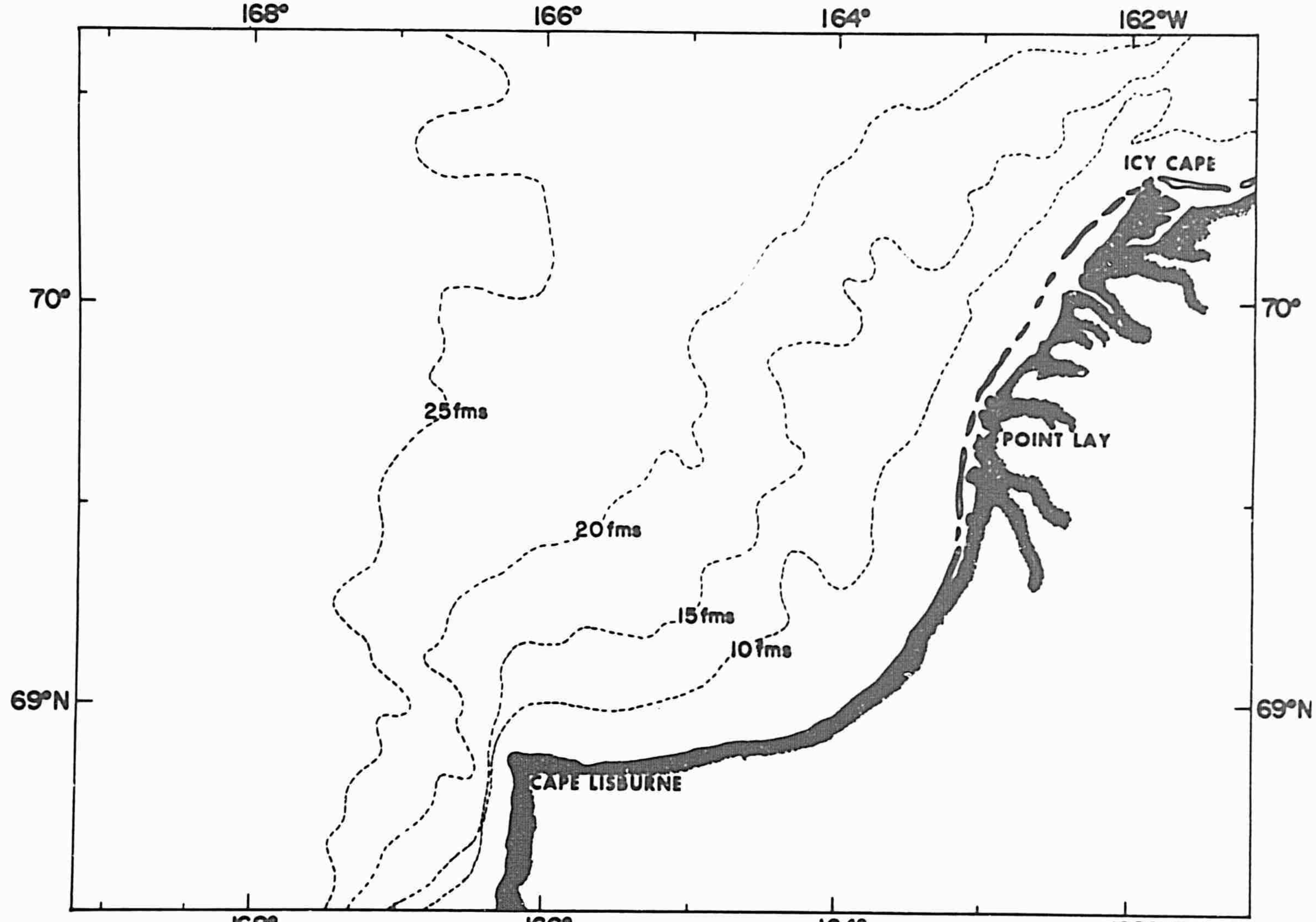


Figure 3.—Bottom depth (fms) off Cape Lisburne-Icy Cape (contoured from data on USC&GS Chart 9402).

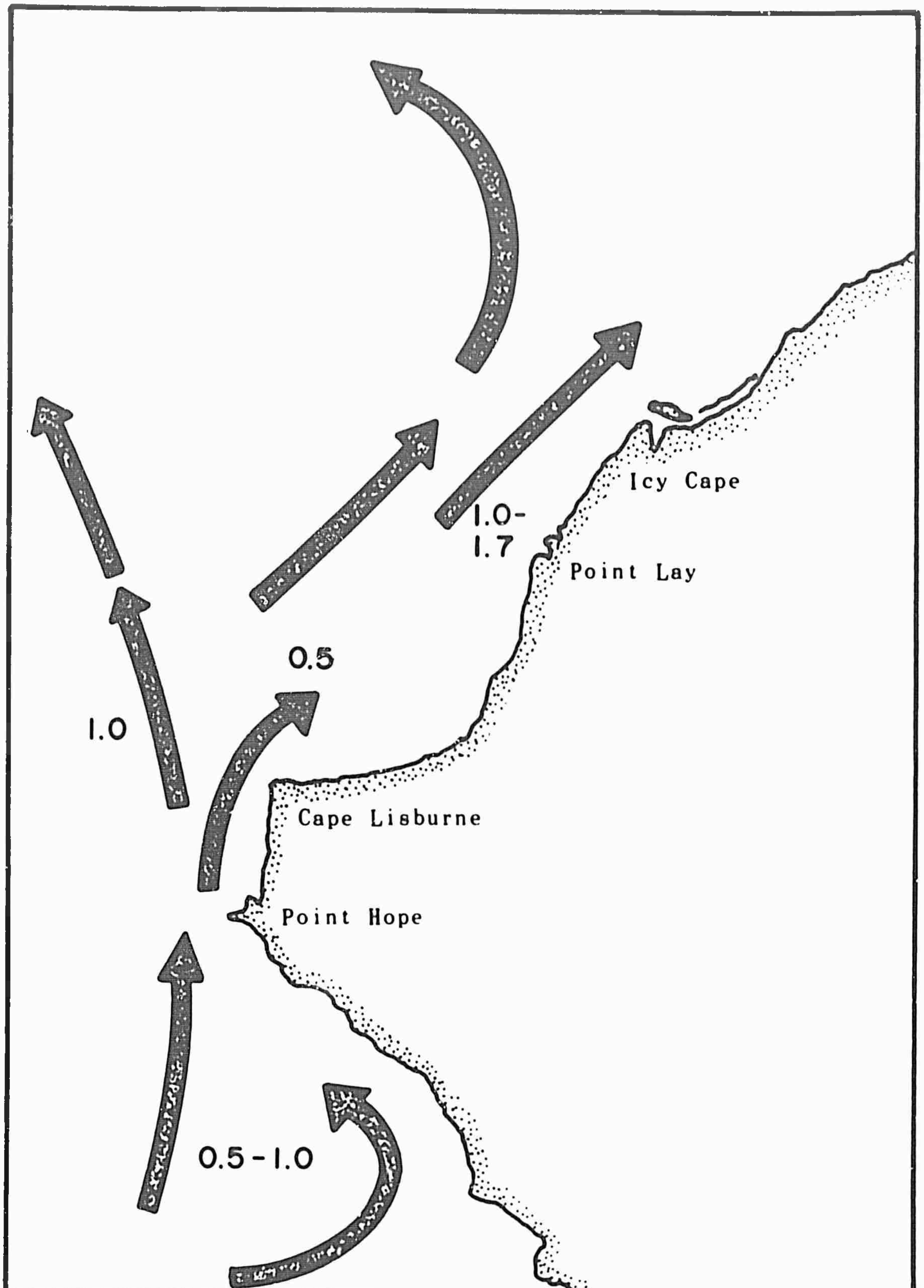


Figure 4.—Average surface current velocities (from USNHO Oceanographic Atlas of the Polar Seas—Part II, 1968).

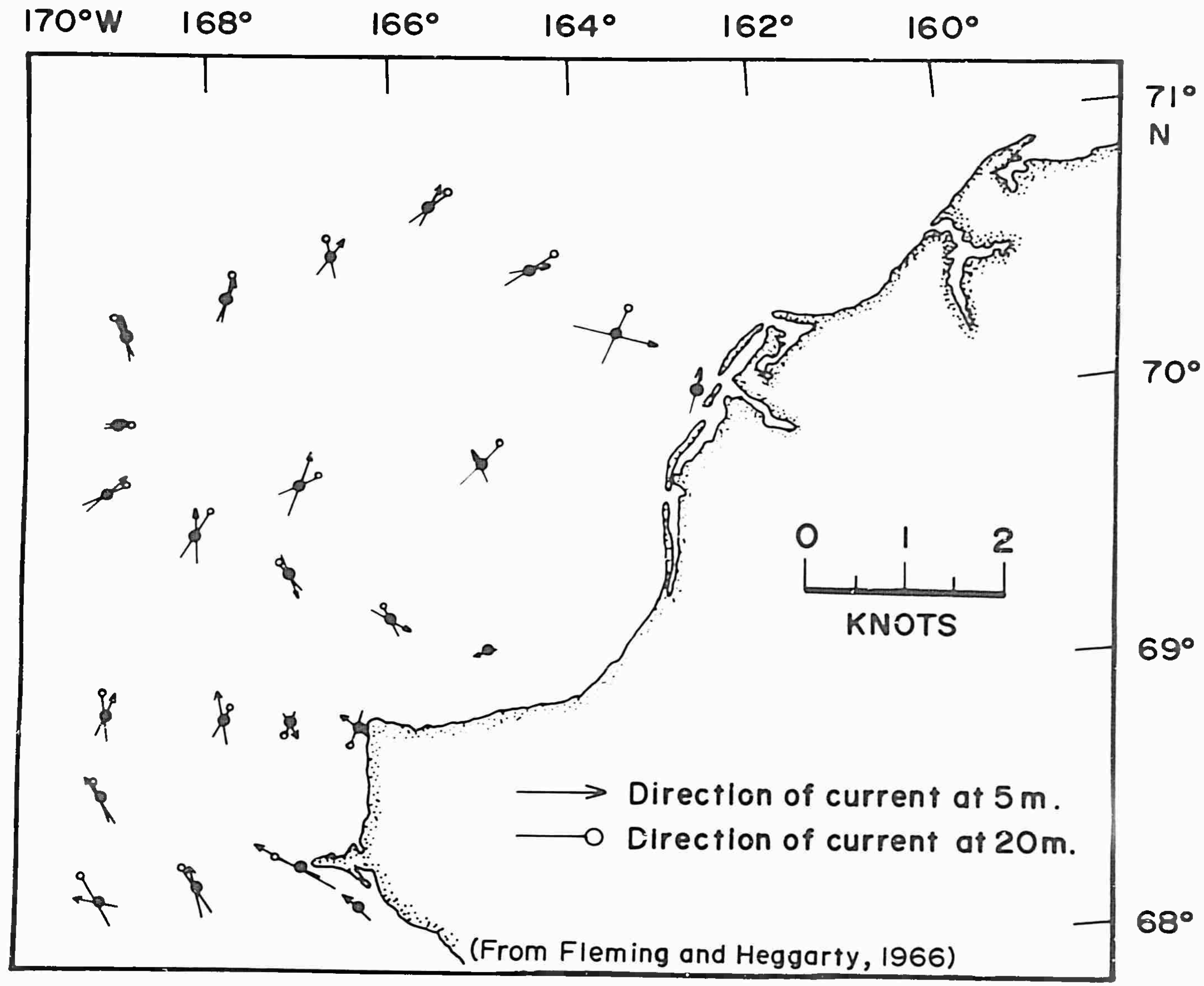


Figure 5.—Current velocities at 5 and 20 m as measured by current meter (from Fleming and Heggarty, 1966).

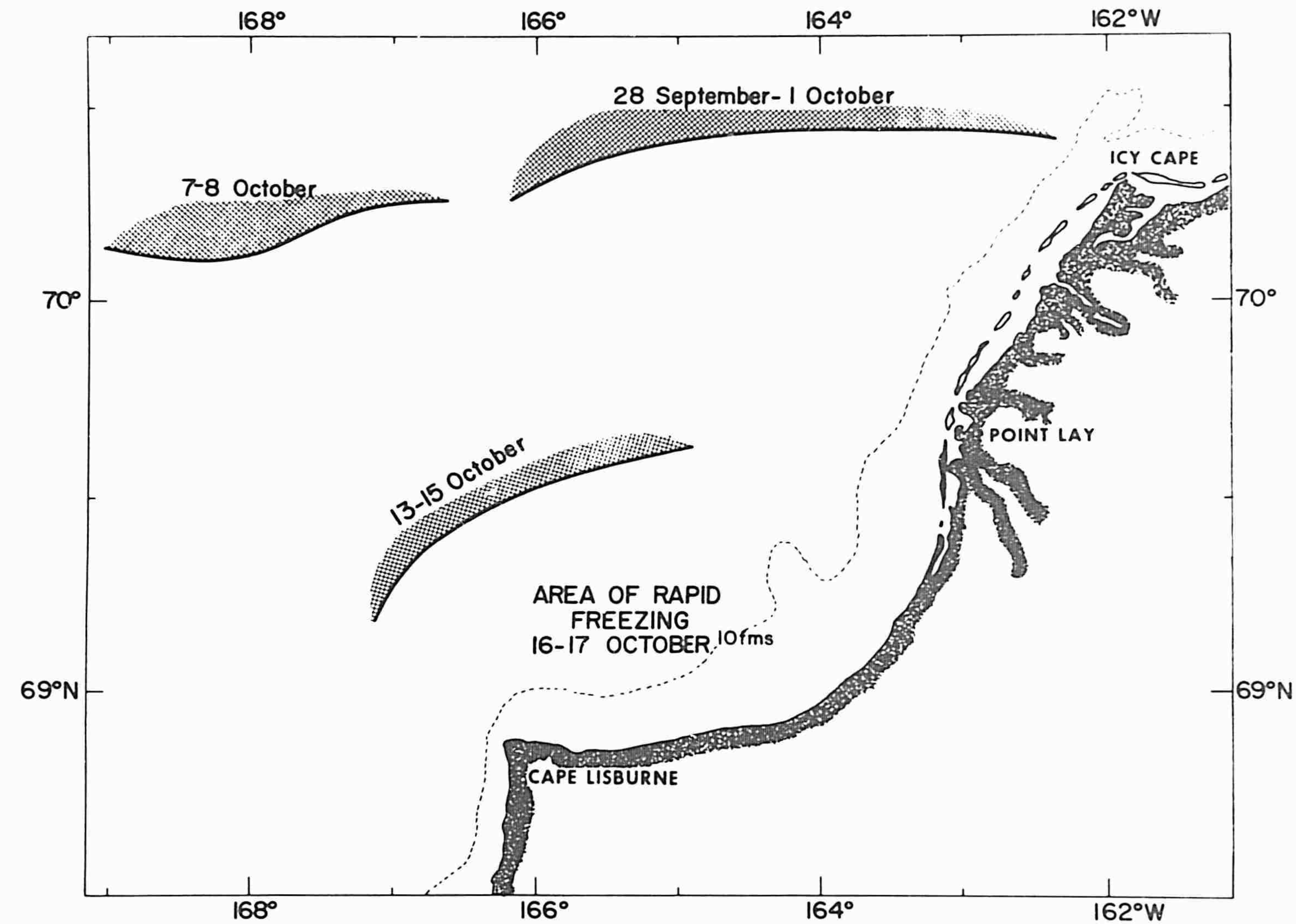
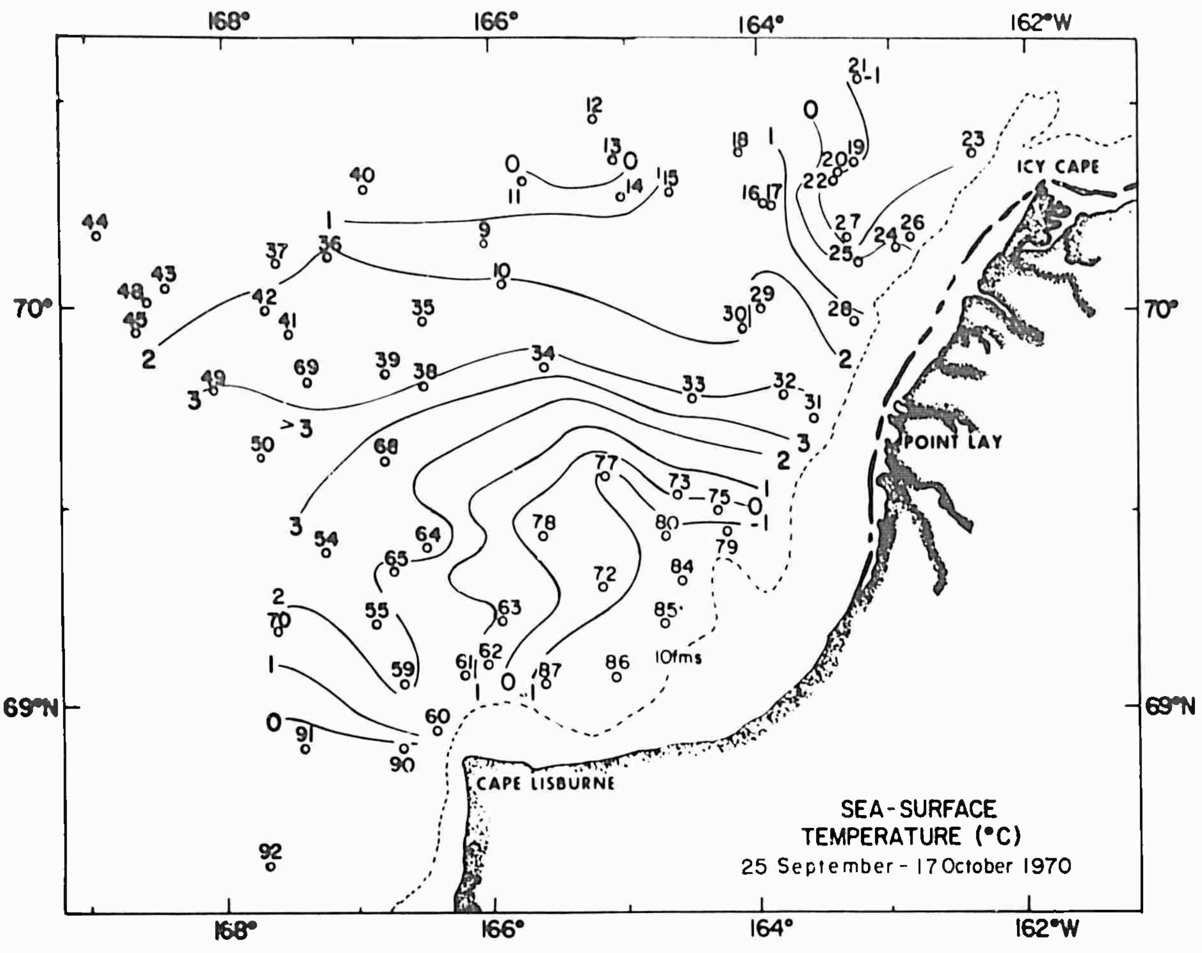


Figure 6.—Location of the edge of the polar ice pack during WEBSEC–70, based on observations made by CGC GLACIER.



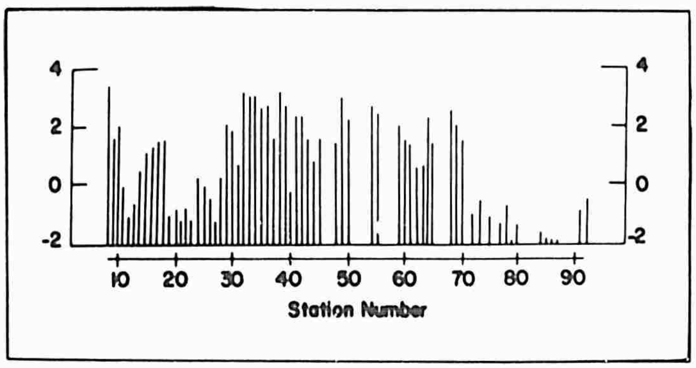


Figure 7.—Sea surface temperature (°C) during WEBSEC-70, 25 September–17 October 1970.

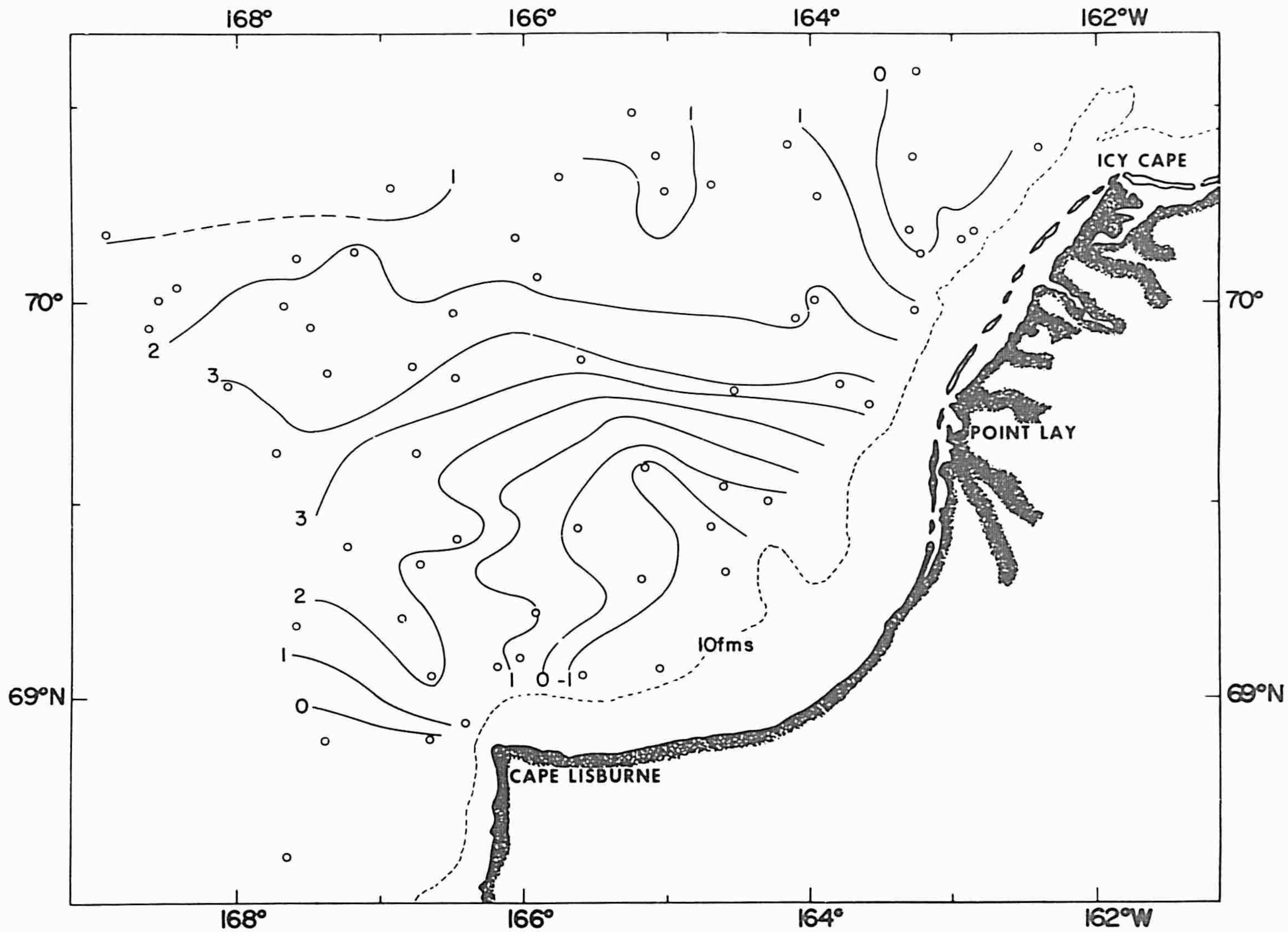


Figure 8.—Temperature (°C) at 10 m during WEBSEC-70, 25 September–17 October 1970.

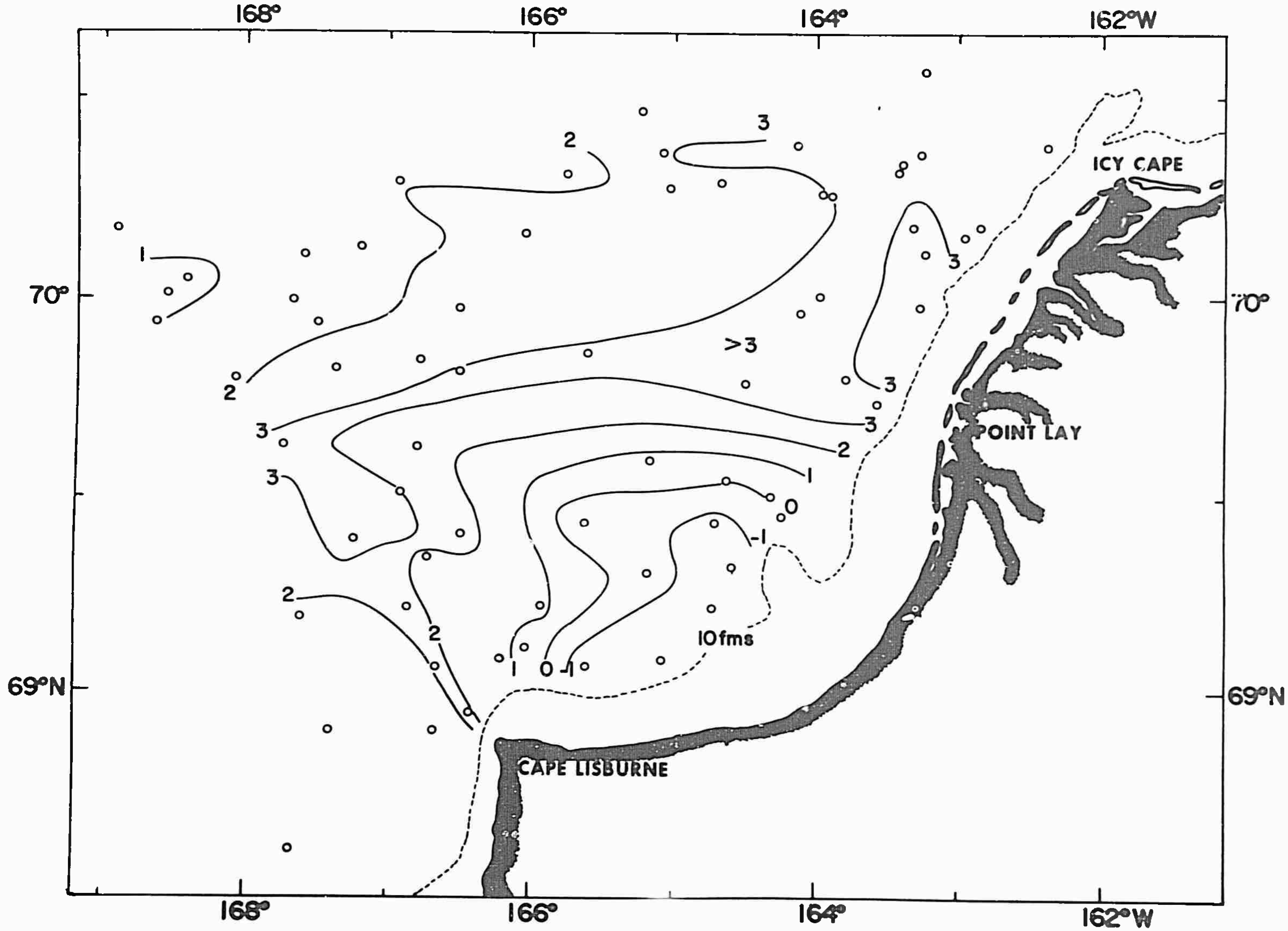


Figure 9.—Near-bottom temperature (°C) during WEBSEC-70, 25 September–17 October 1970.

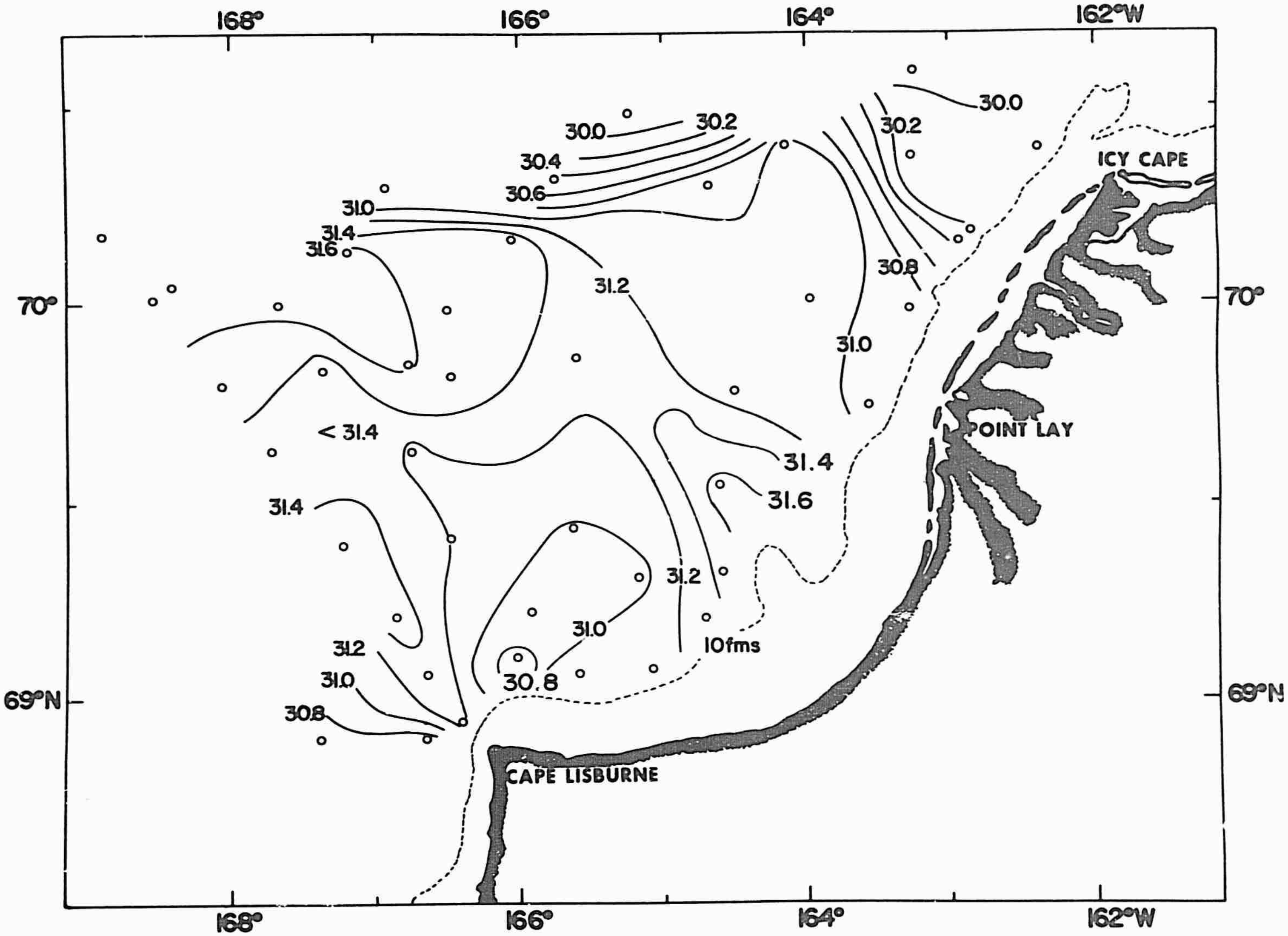


Figure 10.—Sea surface salinity (‰) during WEBSEC-70, 25 September–17 October 1970.

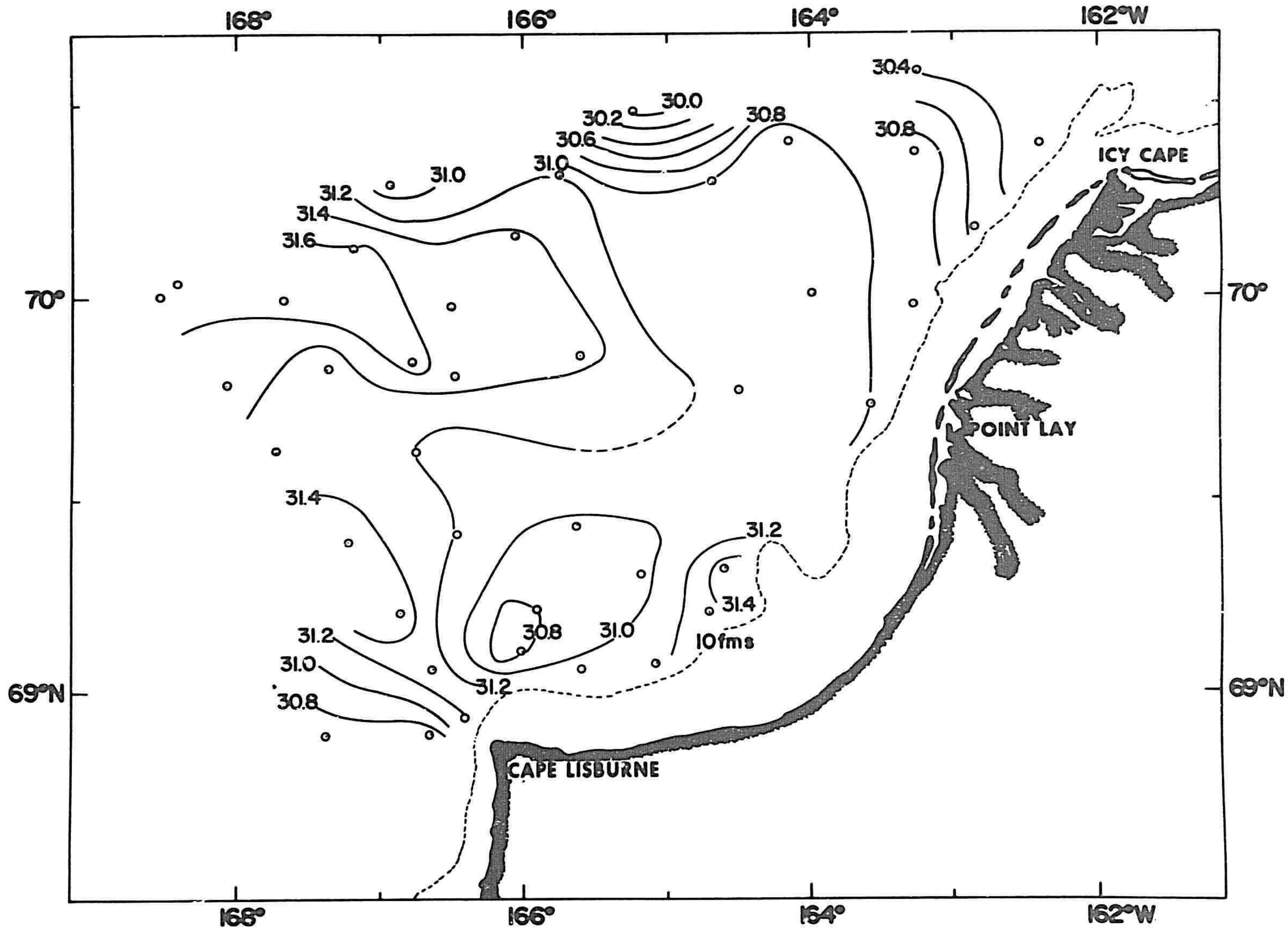


Figure 11.—Salinity (‰) at 10 m during WEBSEC-70, 25 September–17 October 1970.

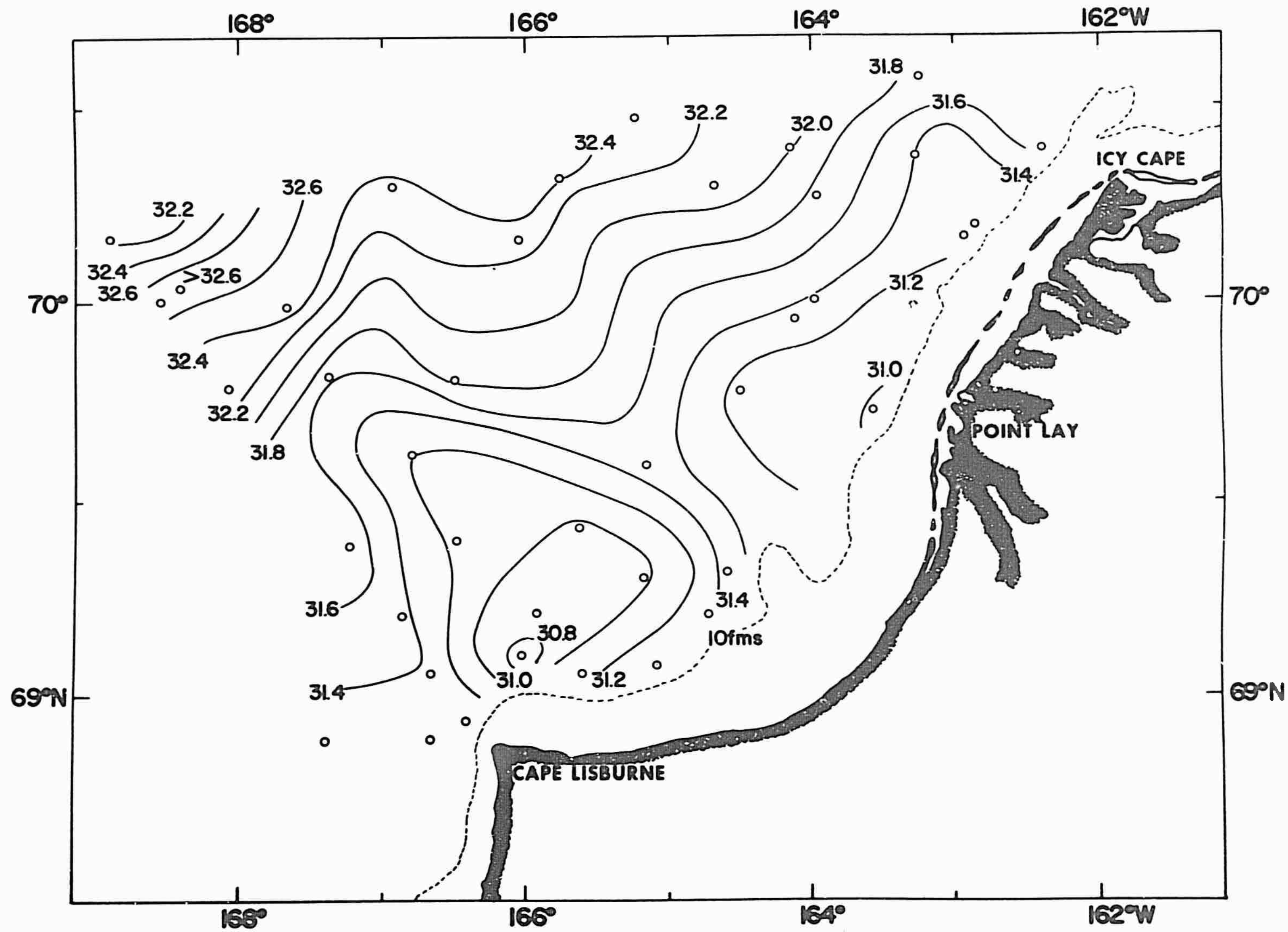


Figure 12.—Near-bottom salinity (‰) during WEBSEC-70, 25 September–17 October 1970.

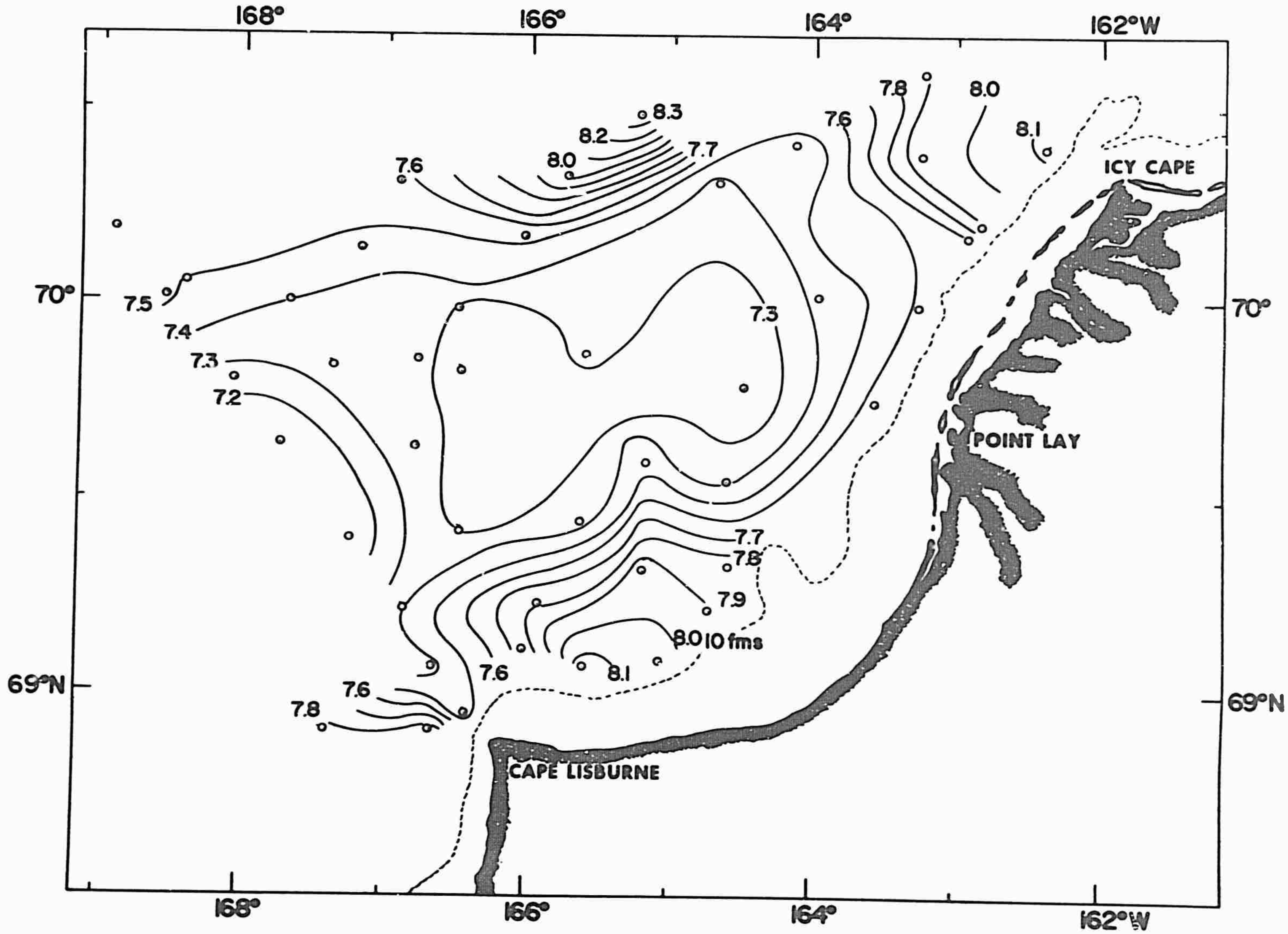


Figure 13.—Dissolved oxygen concentration (ml/l) at the sea surface during WEBSEC–70, 25 September–17 October 1970.

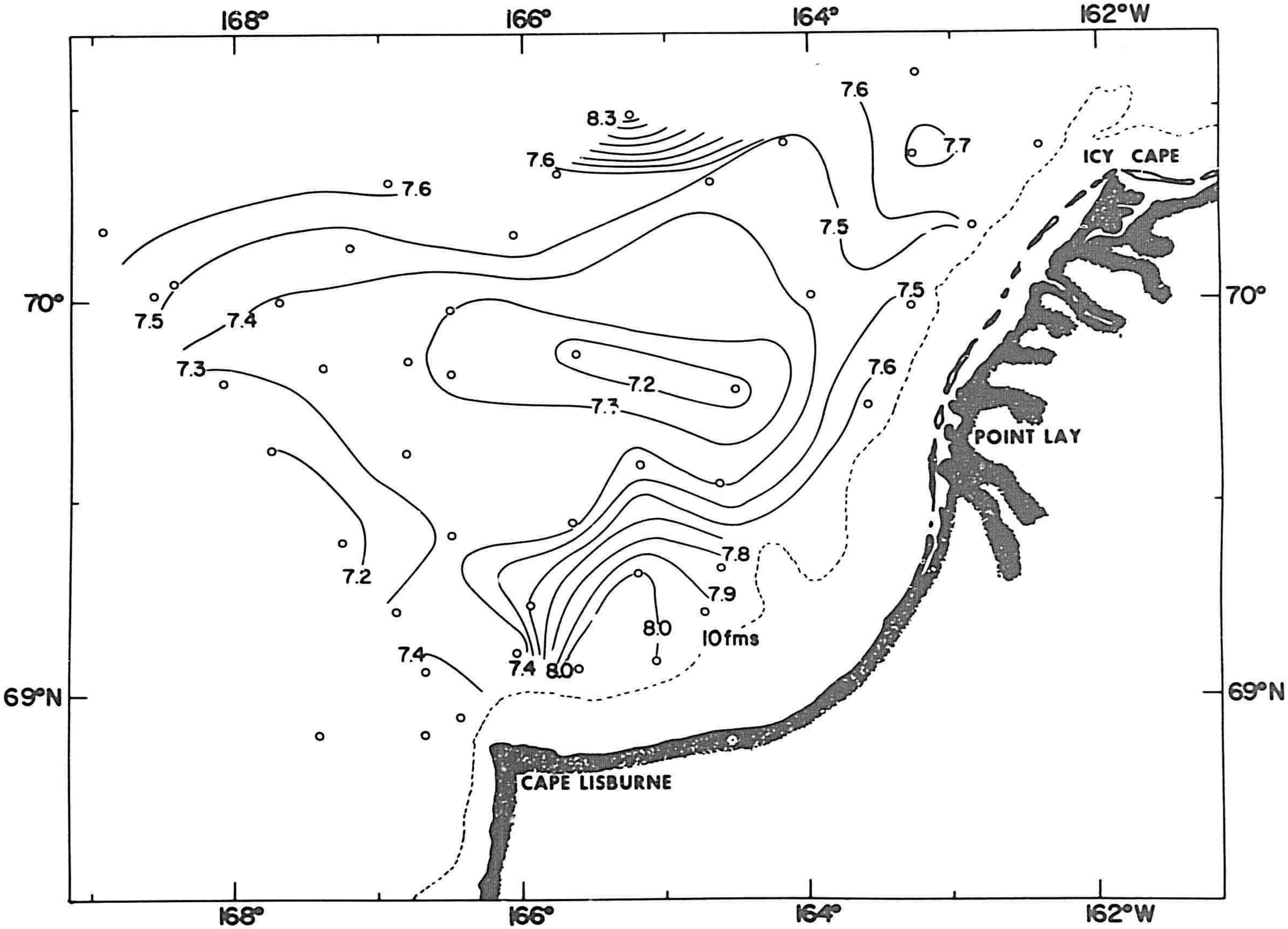


Figure 14.—Dissolved oxygen concentration (ml/l) at 10 m during WEBSEC-70, 25 September–17 October 1970.

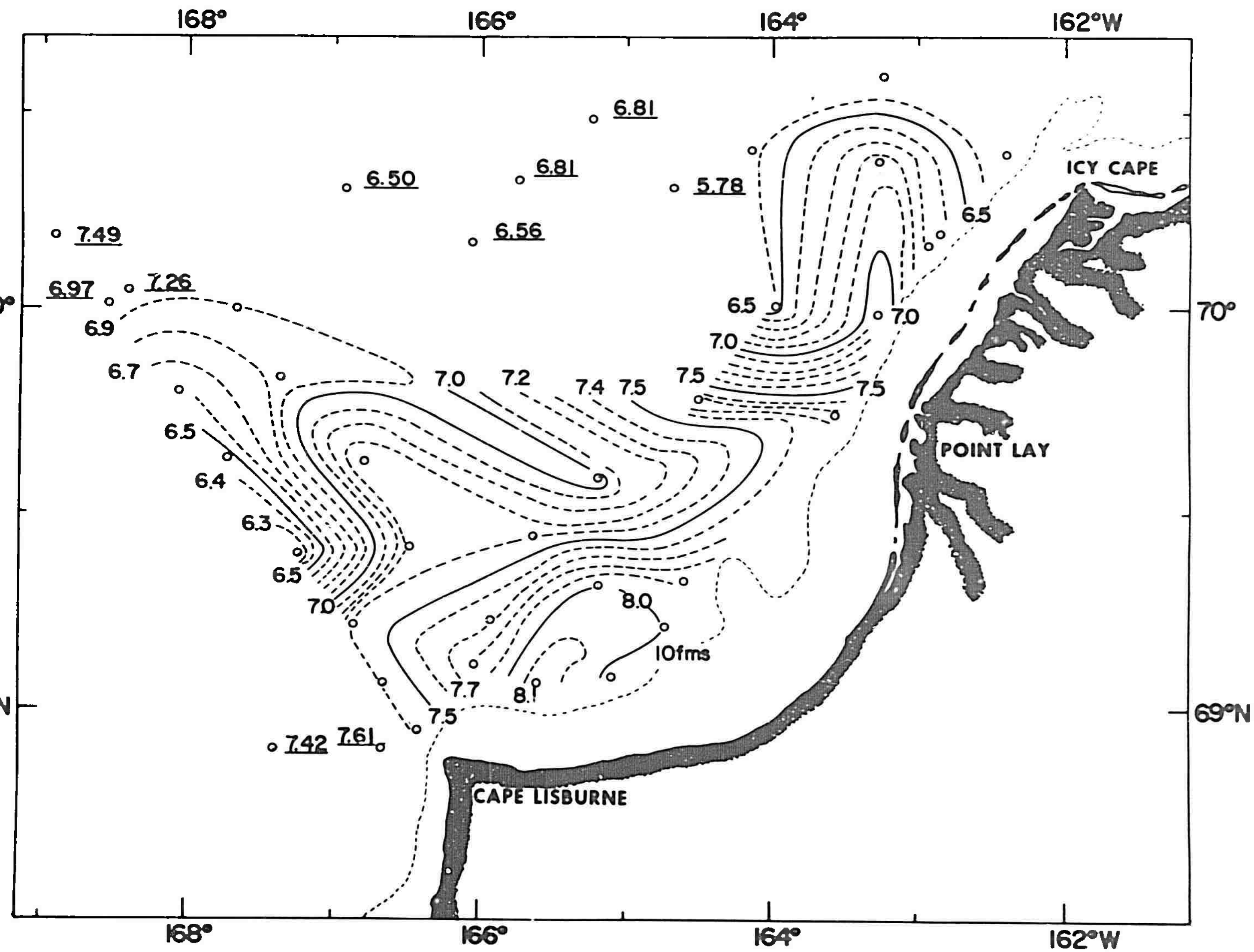


Figure 15.—Dissolved oxygen concentration (ml/l) near bottom during WEBSEC-70, 25 September–17 October 1970

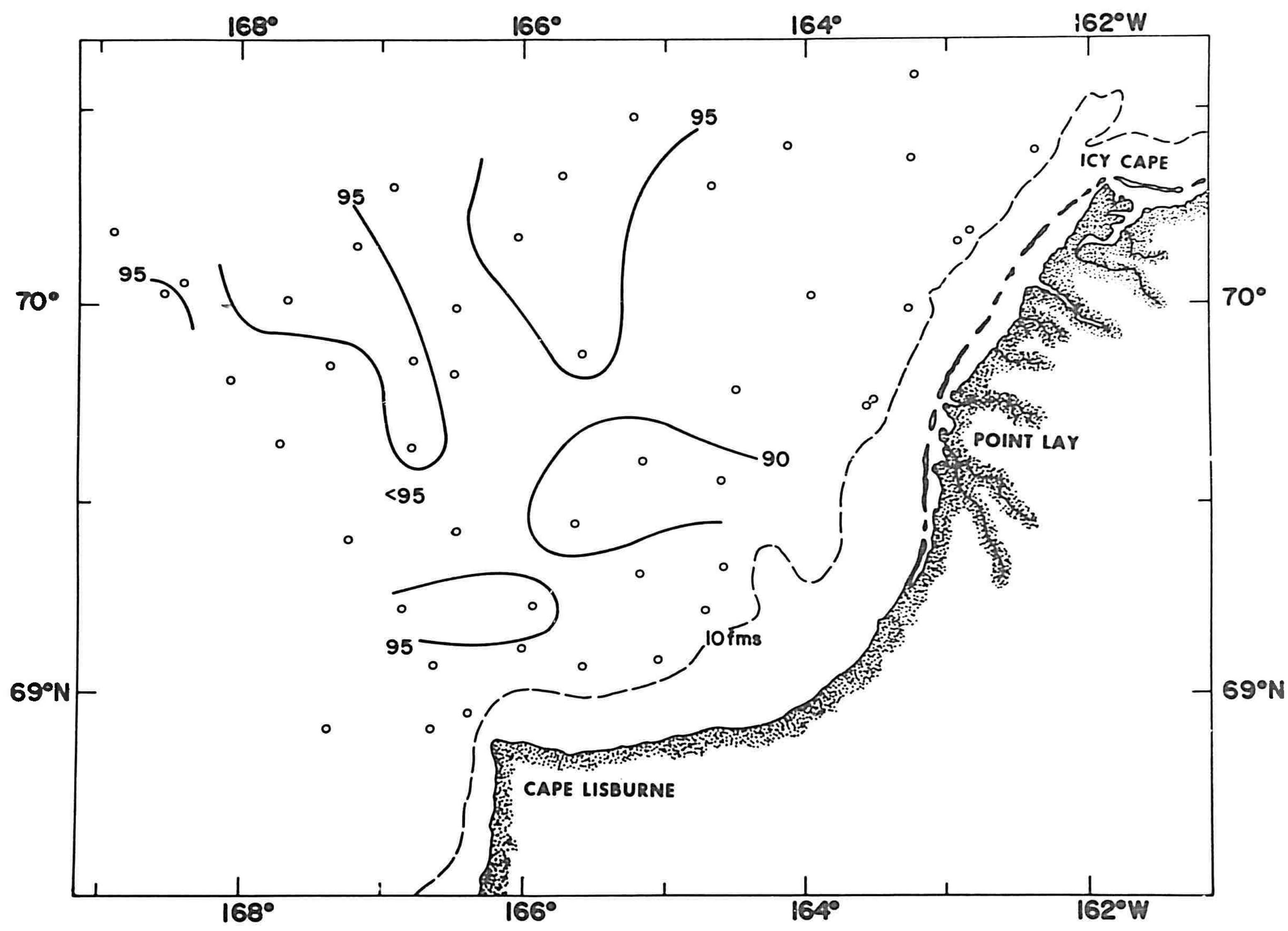


Figure 16.—Percent saturation of dissolved oxygen at the sea surface during WEBSEC-70, 25 September–17 October 1970.

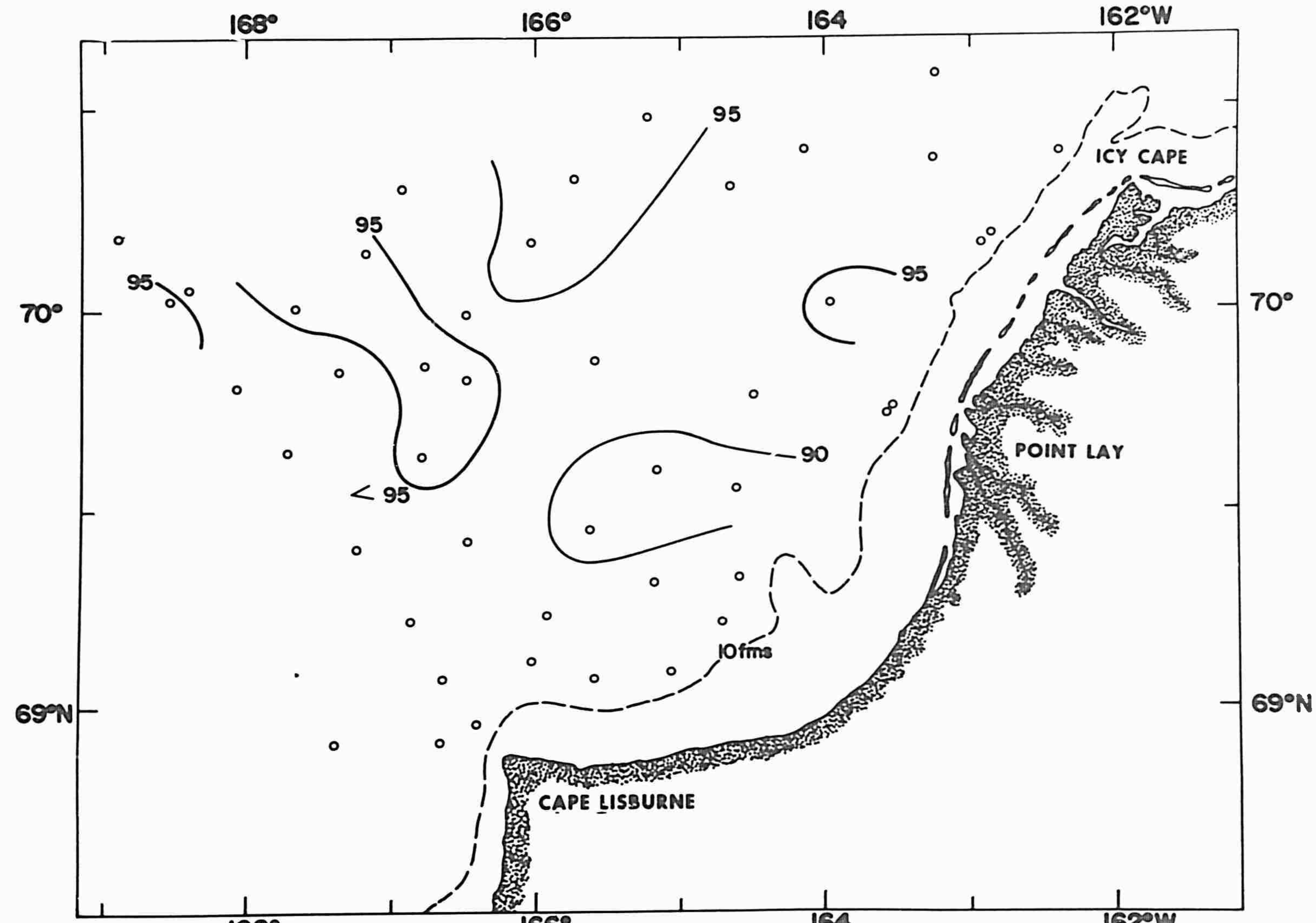


Figure 17.—Percent saturation of dissolved oxygen at 10 m during WEBSEC–70, 25 September–17 October 1970.

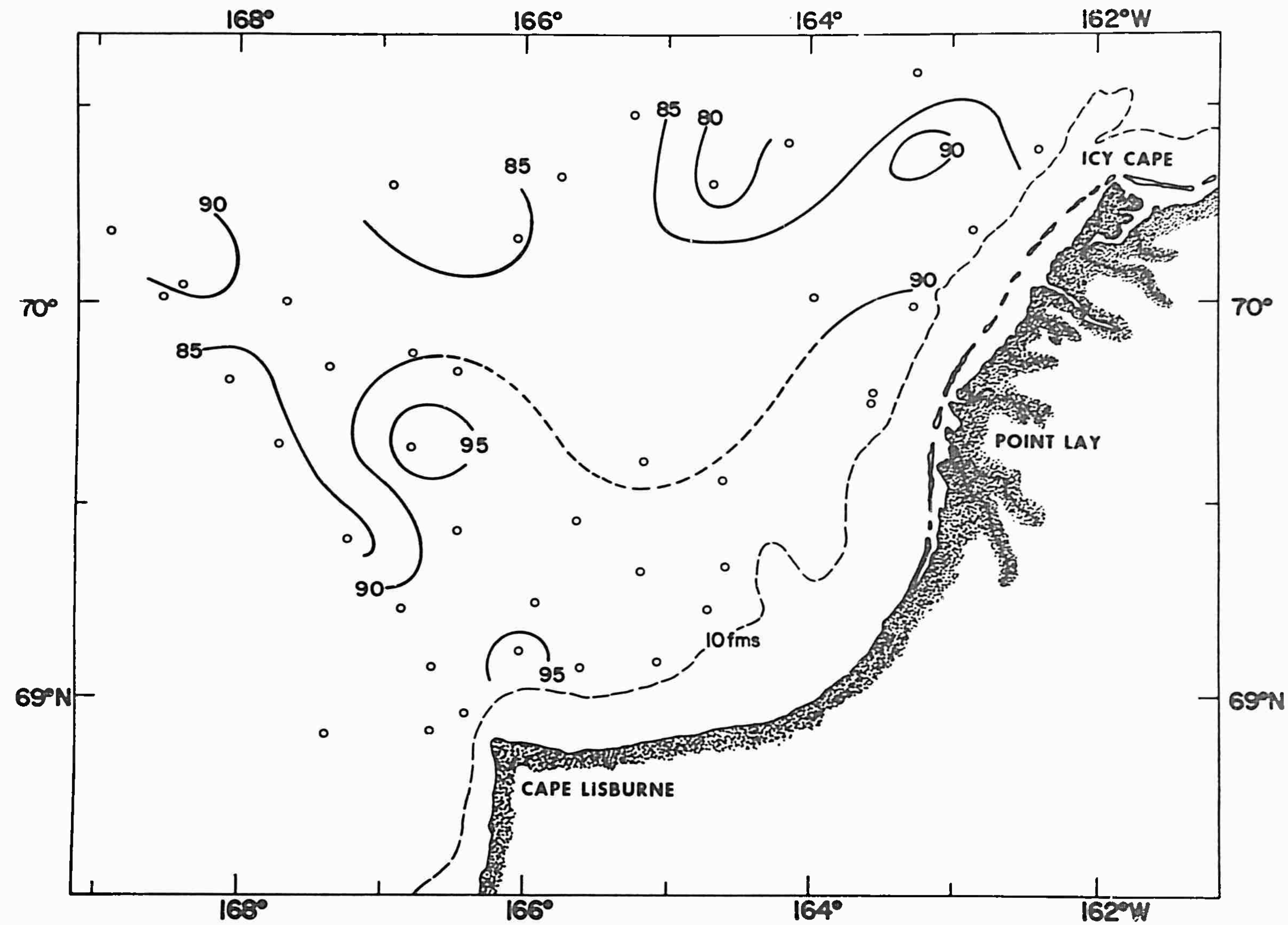


Figure 18.—Percent saturation of dissolved oxygen near bottom during WEBSEC-70, 25 September–17 October 1970.

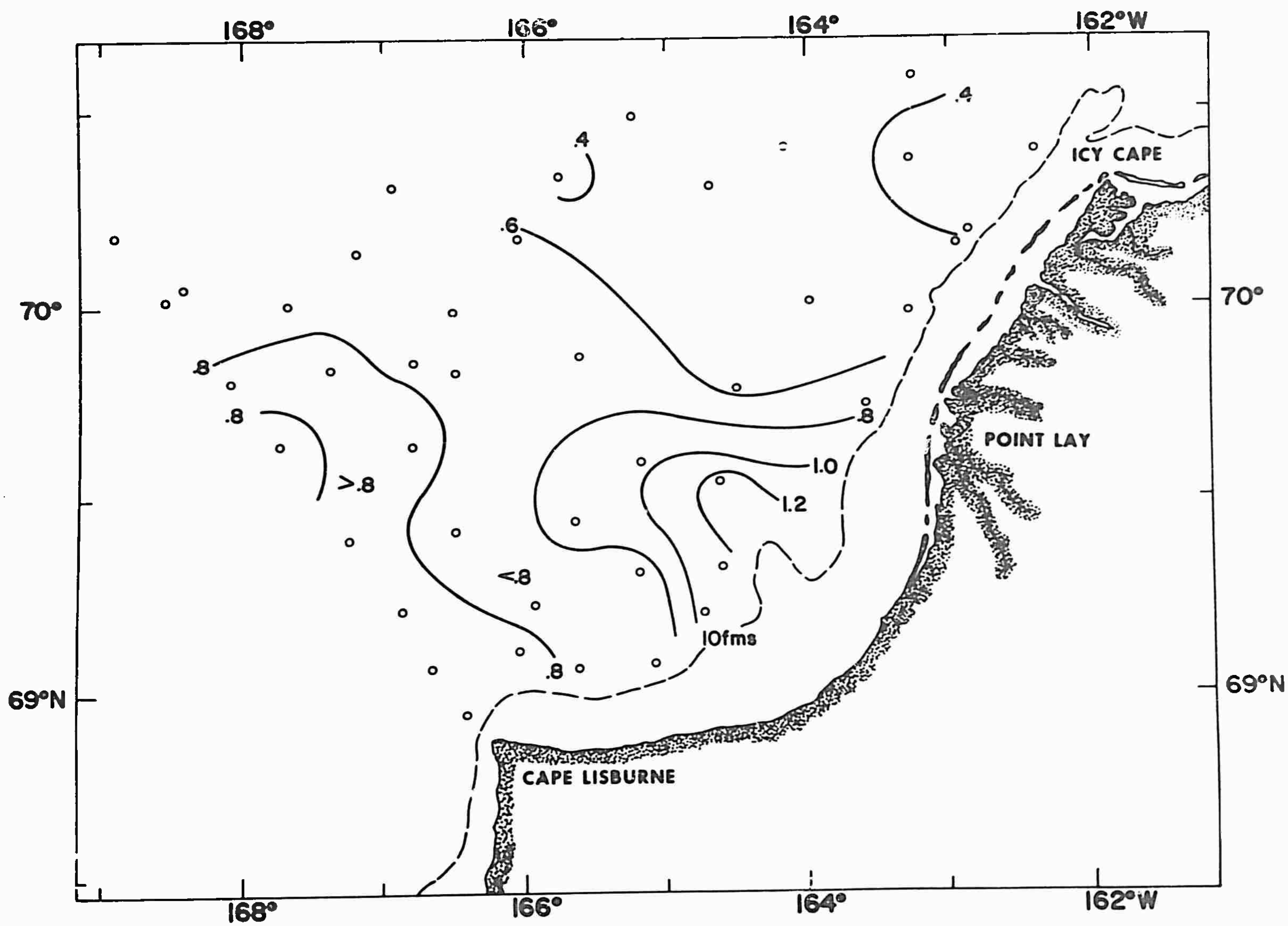


Figure 19.—Concentration of dissolved inorganic phosphate (μg-at/l) at the sea surface during WEBSEC–70, 25 September–17 October 1970.

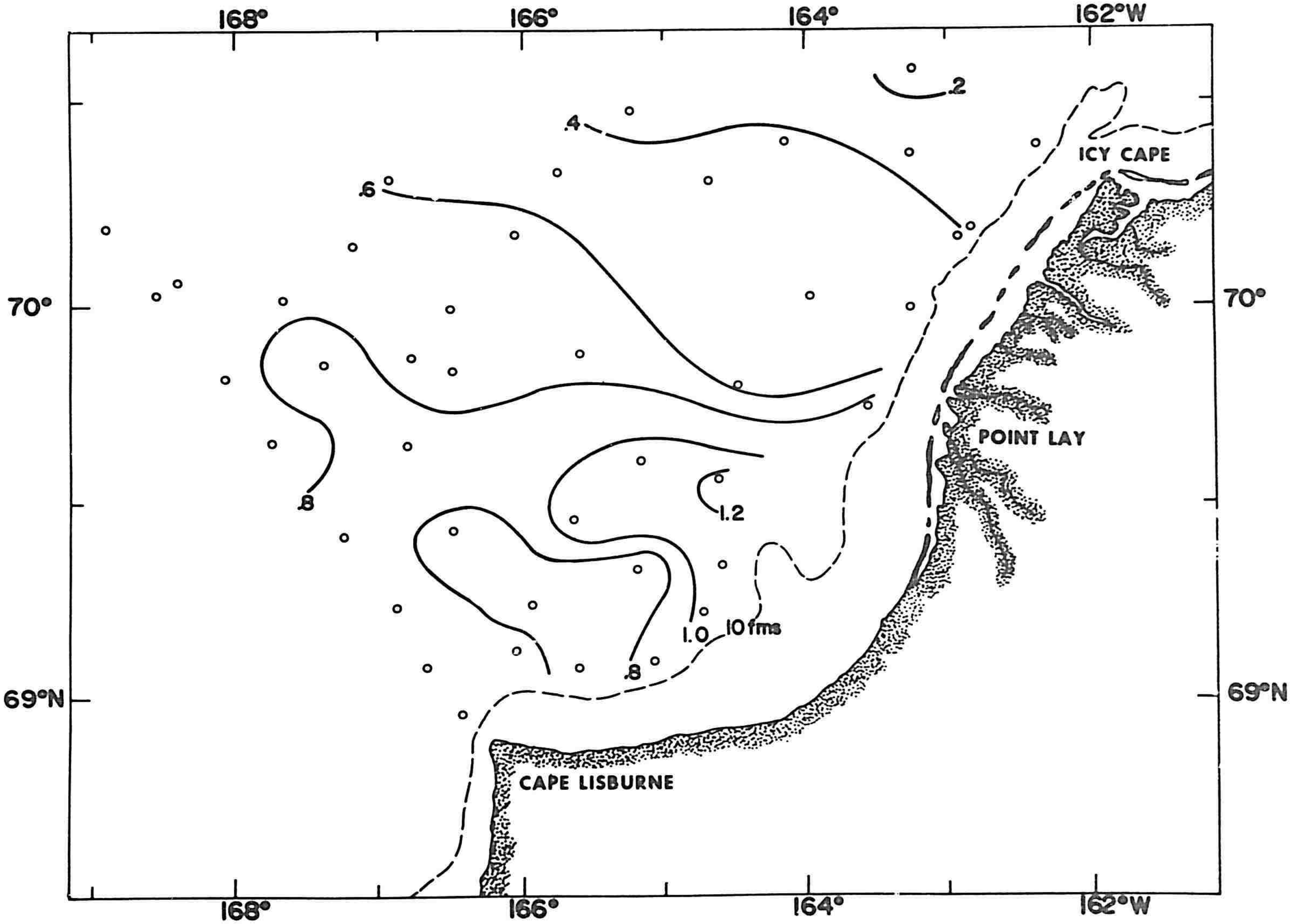


Figure 20.—Concentration of dissolved inorganic phosphate (μg-at/l) at 10 m during WEBSEC-70, 25 September–17 October 1970.

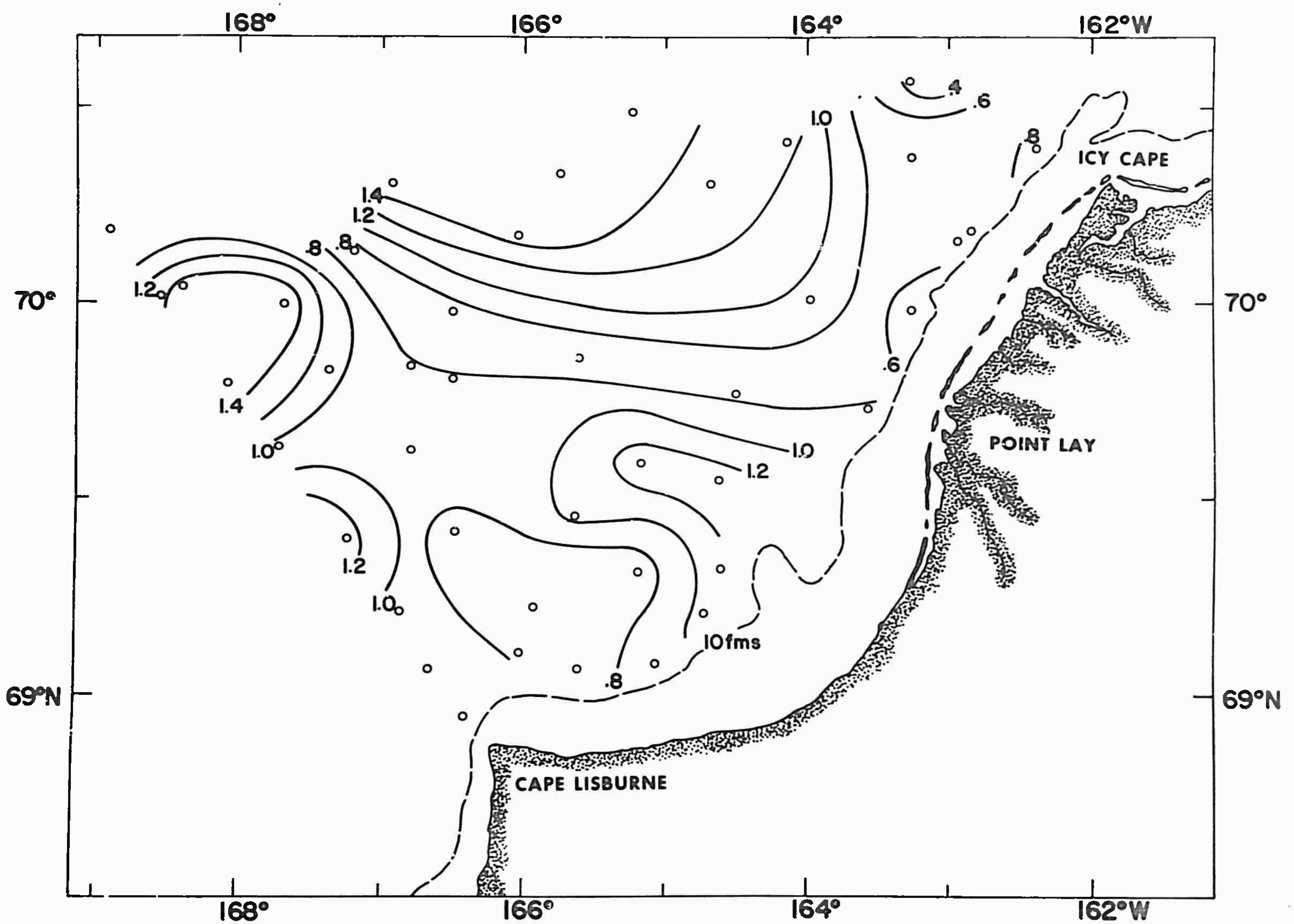


Figure 21.—Concentration of dissolved inorganic phosphate (μg-at/l) near bottom during WEBSEC–70, 25 September–17 October 1970.

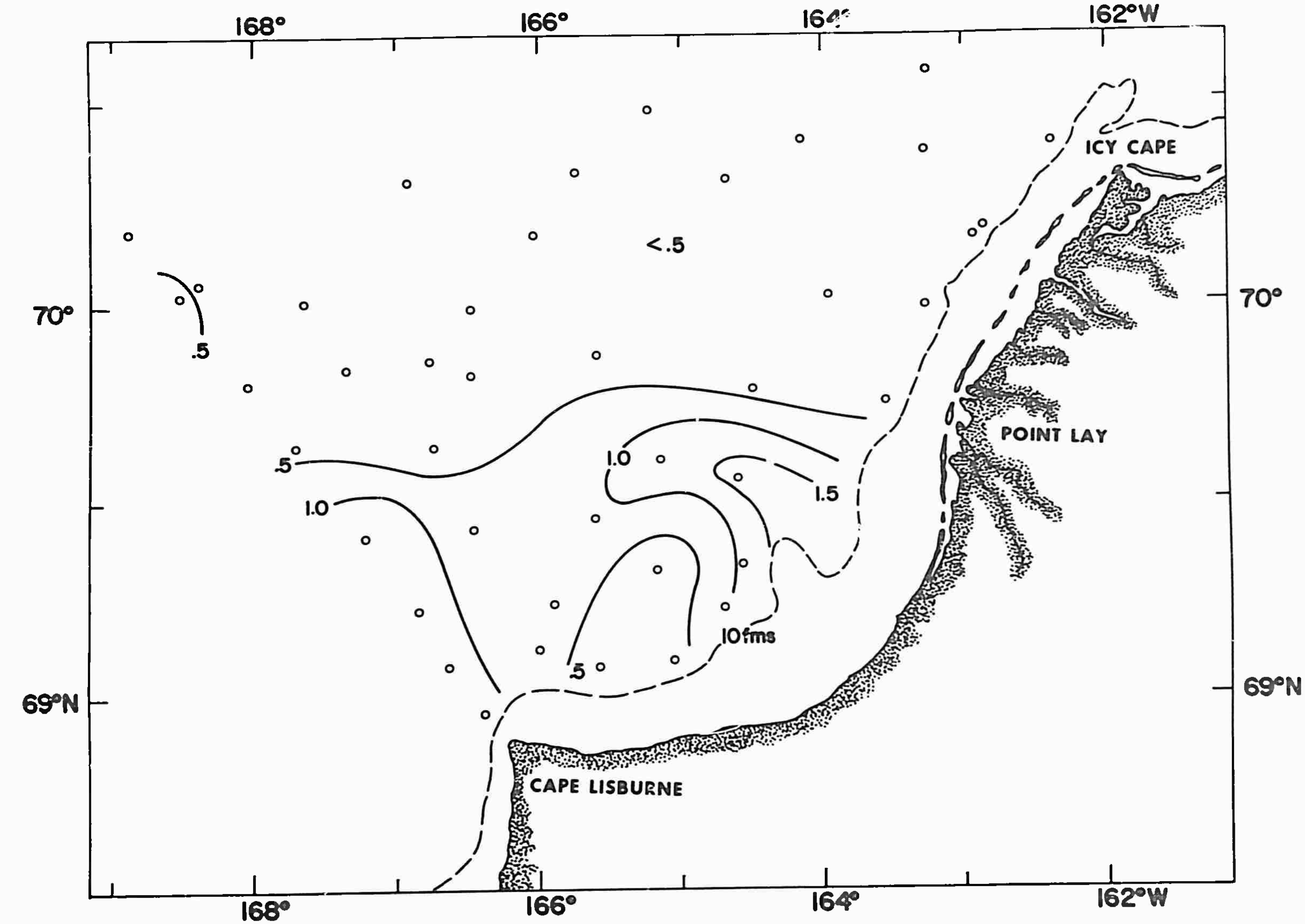


Figure 22.—Concentration of dissolved nitrate (μg-at/l) at the sea surface during WEBSEC–70, 25 September–17 October 1970.

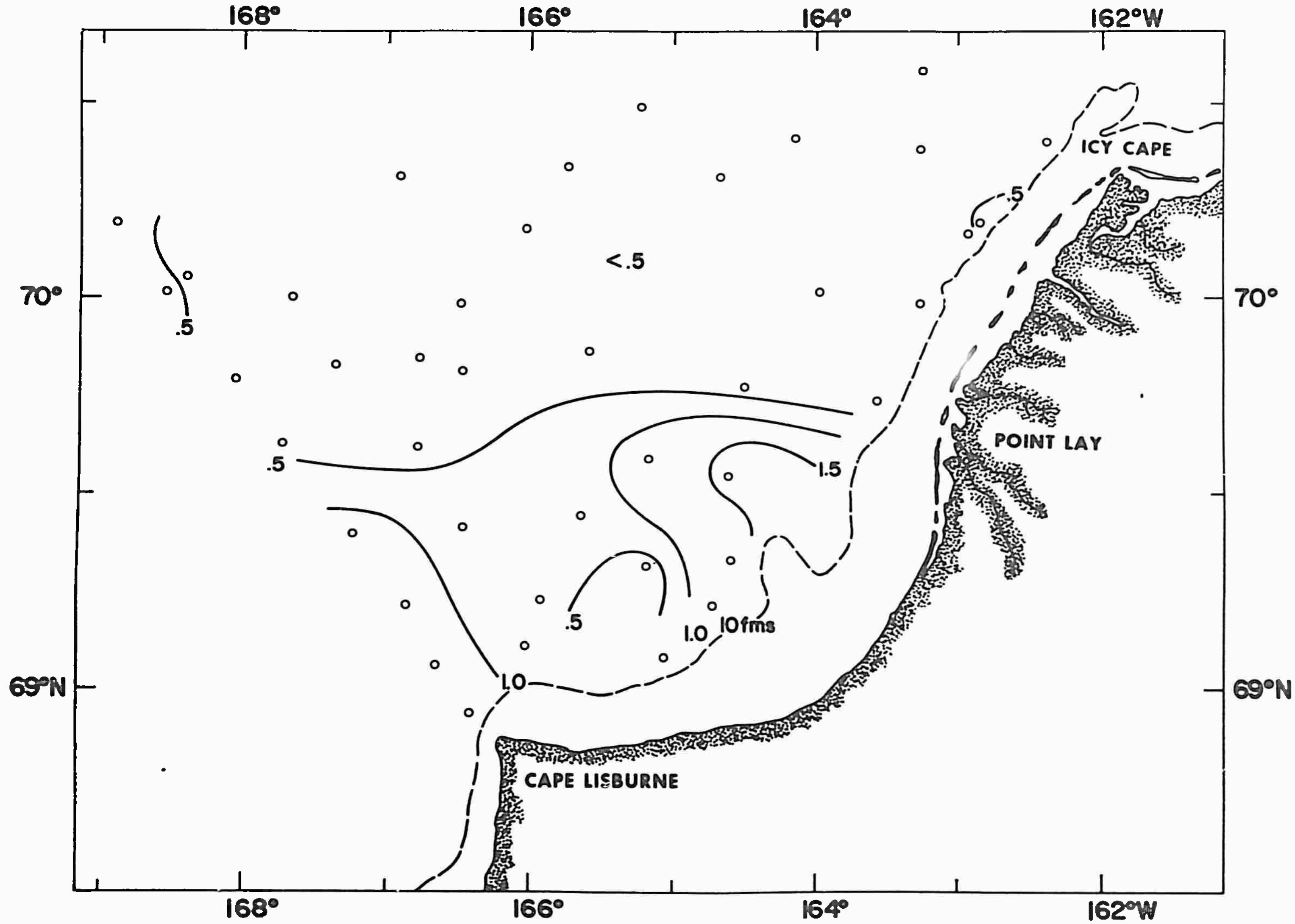


Figure 23.—Concentration of dissolved nitrate (μg-at/l) at 10 m during WEBSEC–70, 25 September–17 October 1970.

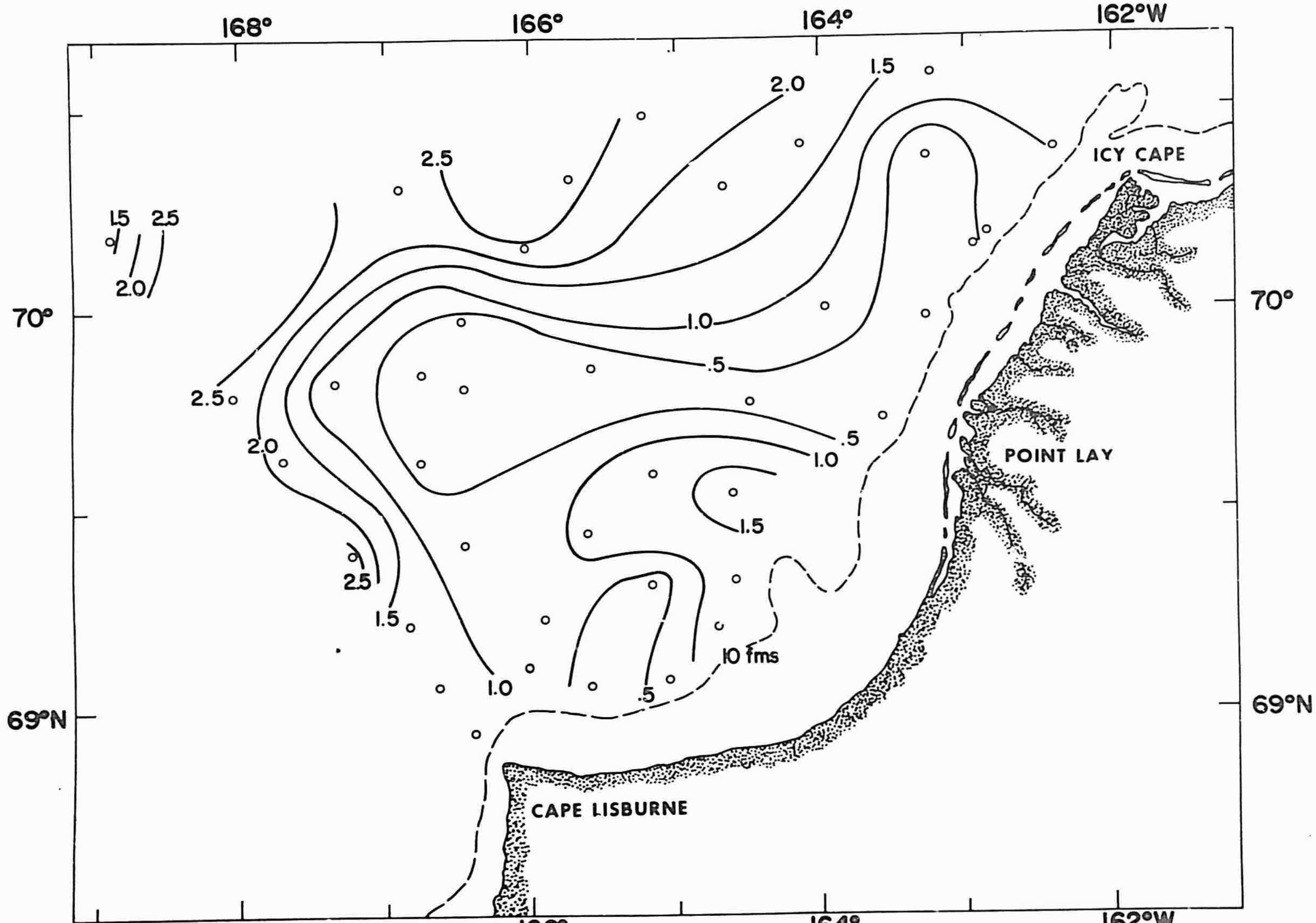


Figure 24.—Concentration of dissolved nitrate (μg-at/l) near bottom during WEBSEC–70, 25 September–17 October 1970.

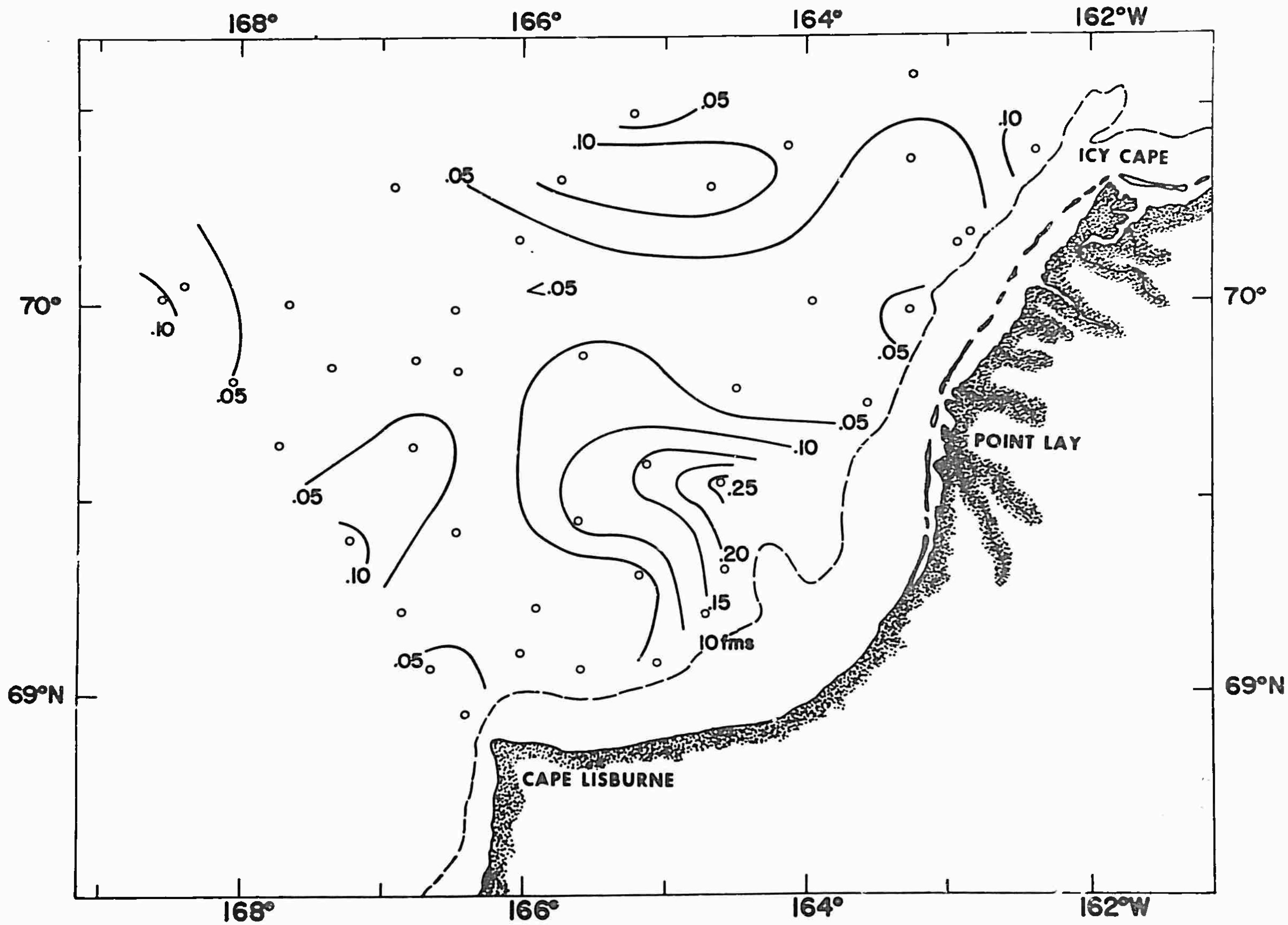


Figure 25.—Concentration of dissolved nitrite (μg-at/l) at the sea surface during WEBSEC-70, 25 September–17 October 1970.

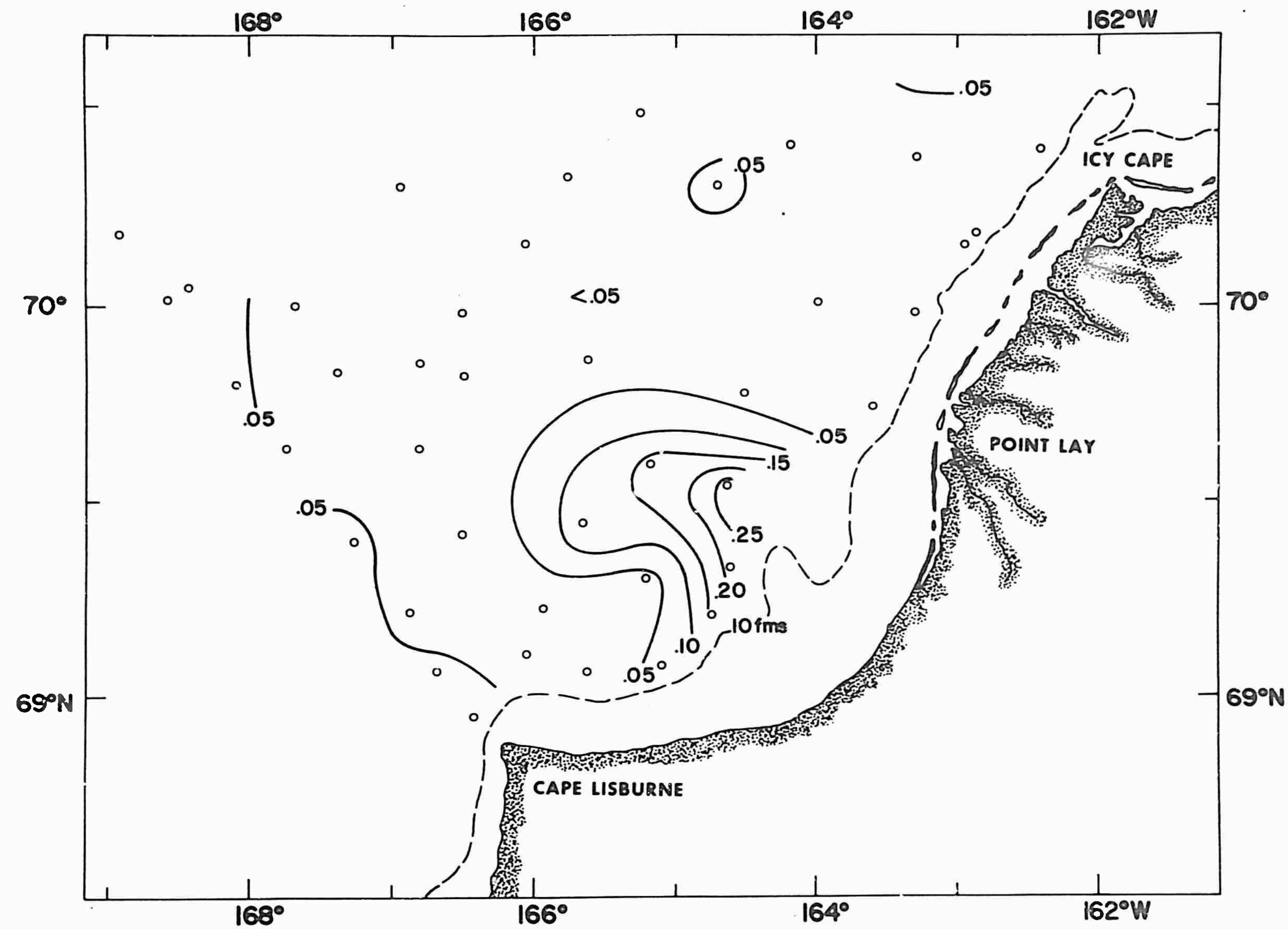


Figure 26.—Concentration of dissolved nitrite (μg-at/l) at 10 m during WEBSEC-70, 25 September–17 October 1970.

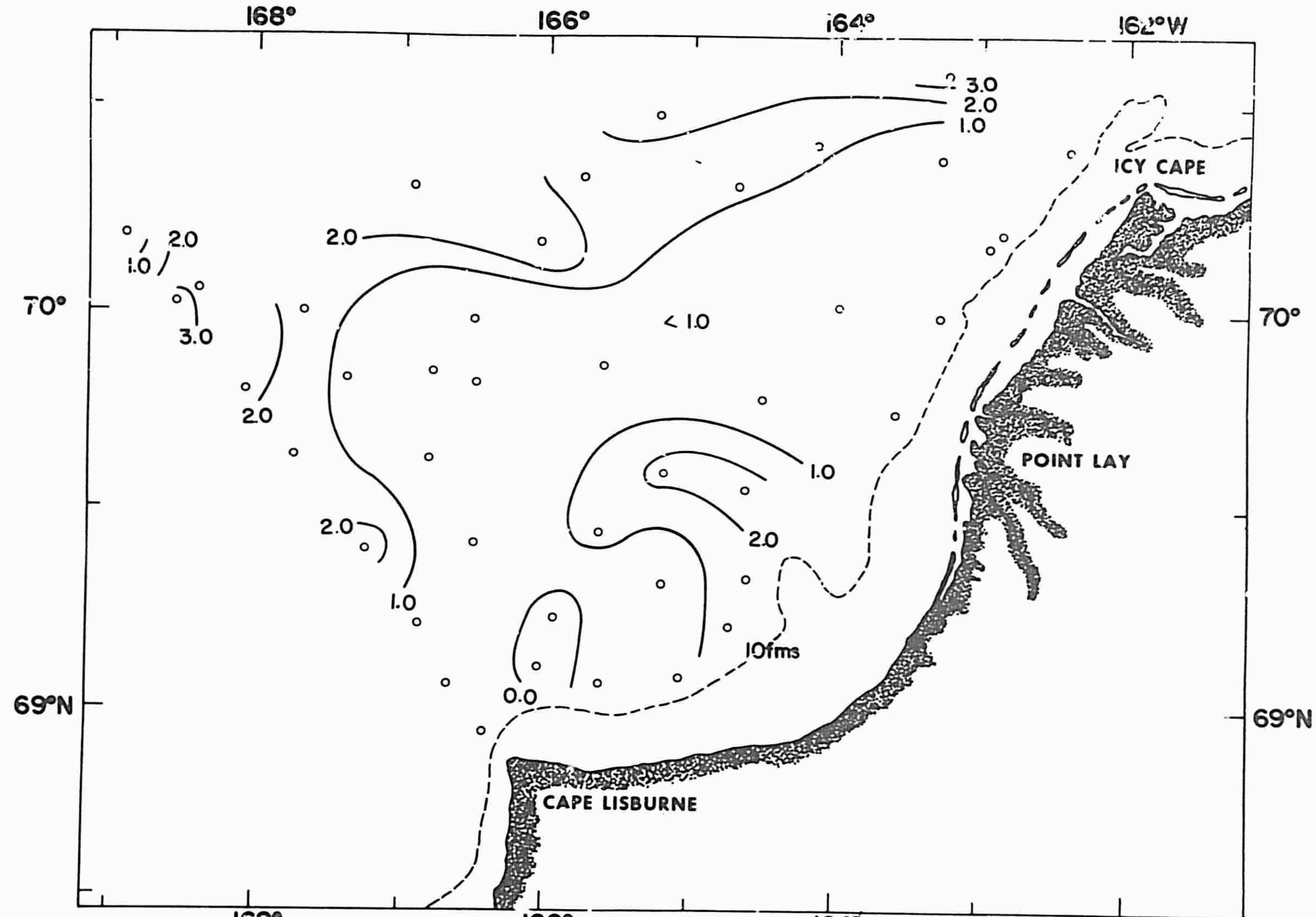


Figure 27.—Concentration of dissolved nitrite (μg-at/l) near bottom during WEBSEC-70, 25 September–17 October 1970.

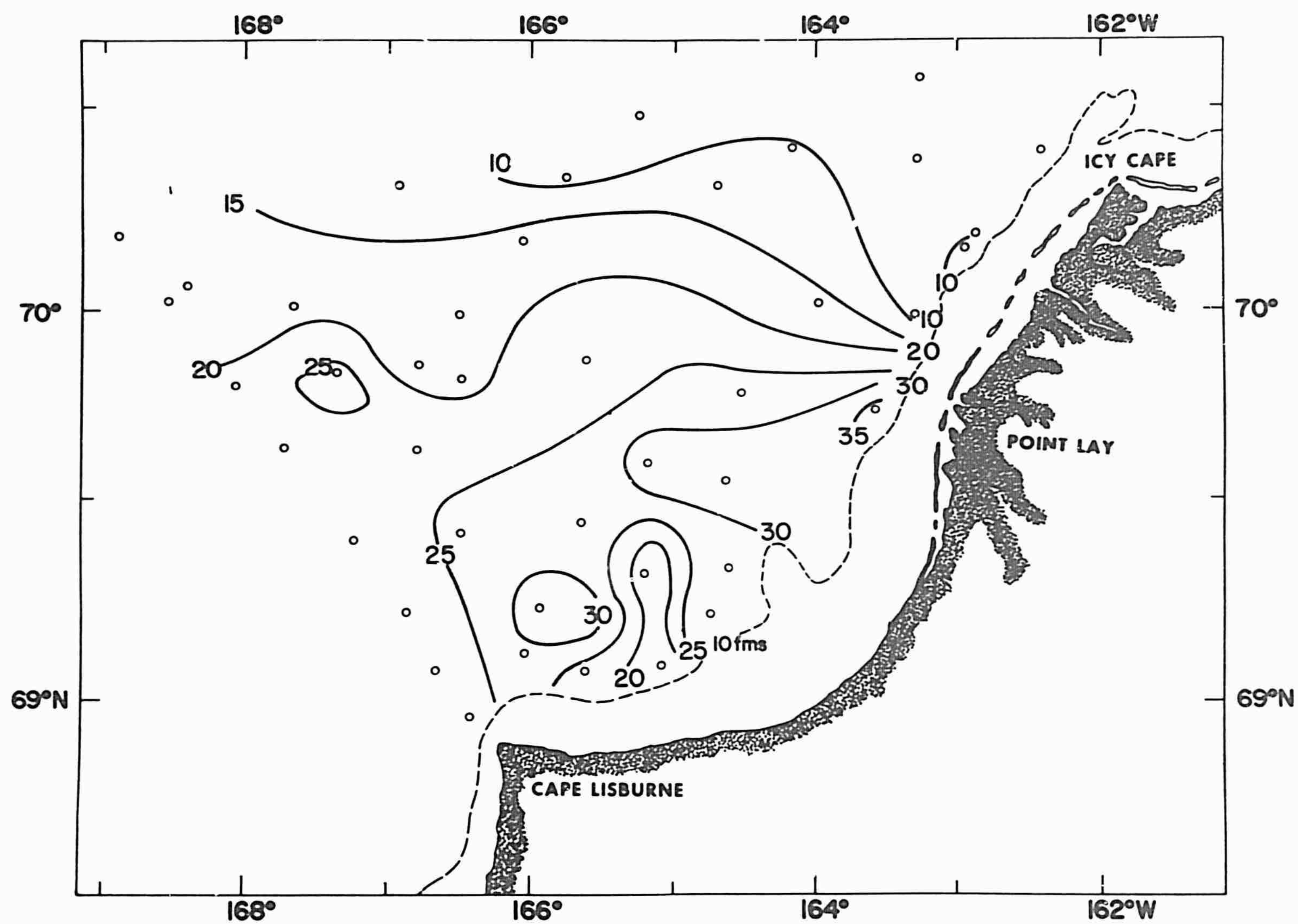


Figure 28.—Concentration of dissolved silicate (μg-at/l) at the sea surface during WEBSEC–70, 25 September–17 October 1970.

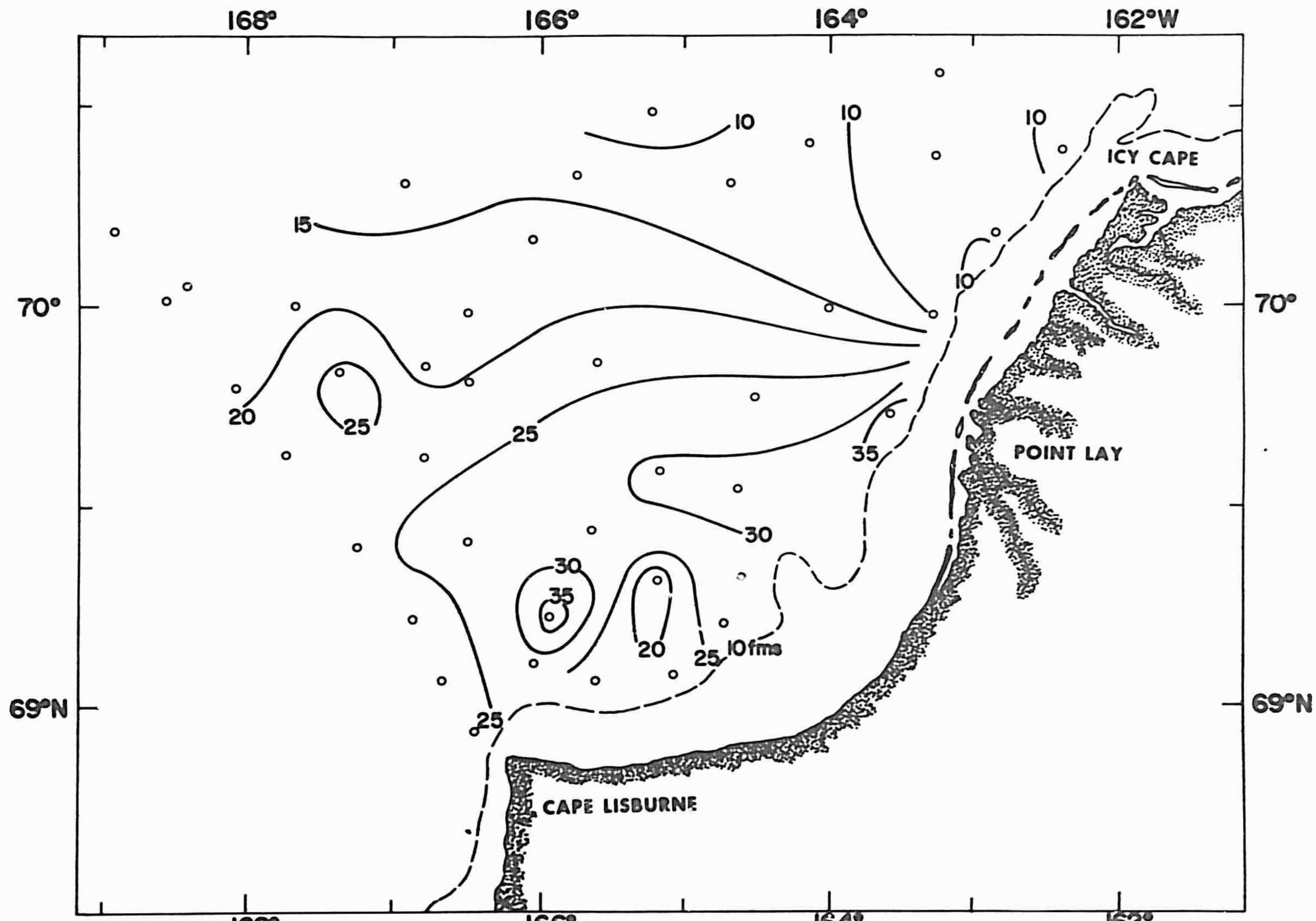


Figure 29.—Concentration of dissolved silicate (μg-at/l) at 10 m during WEBSEC-70, 25 September–17 October 1970.

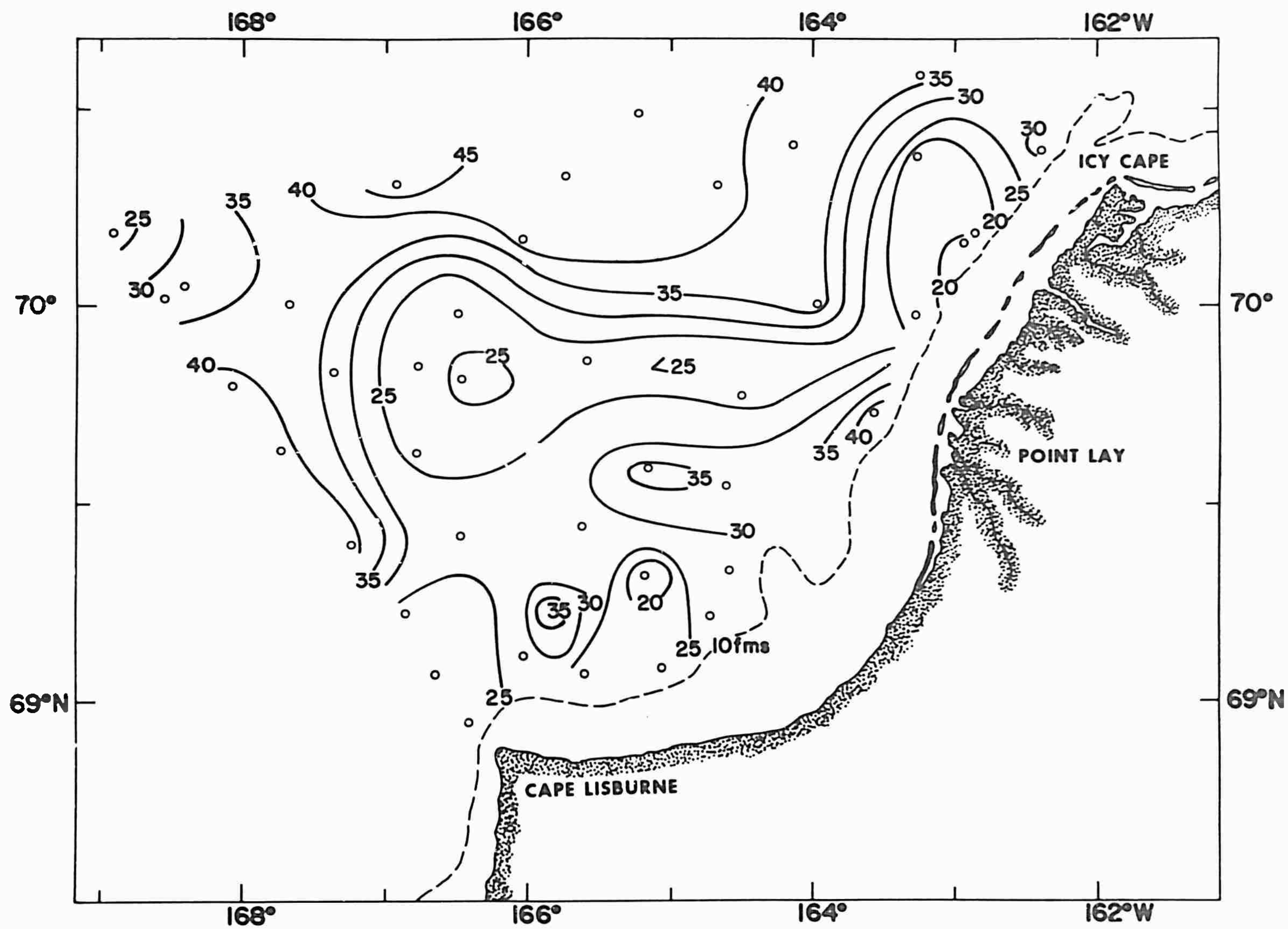
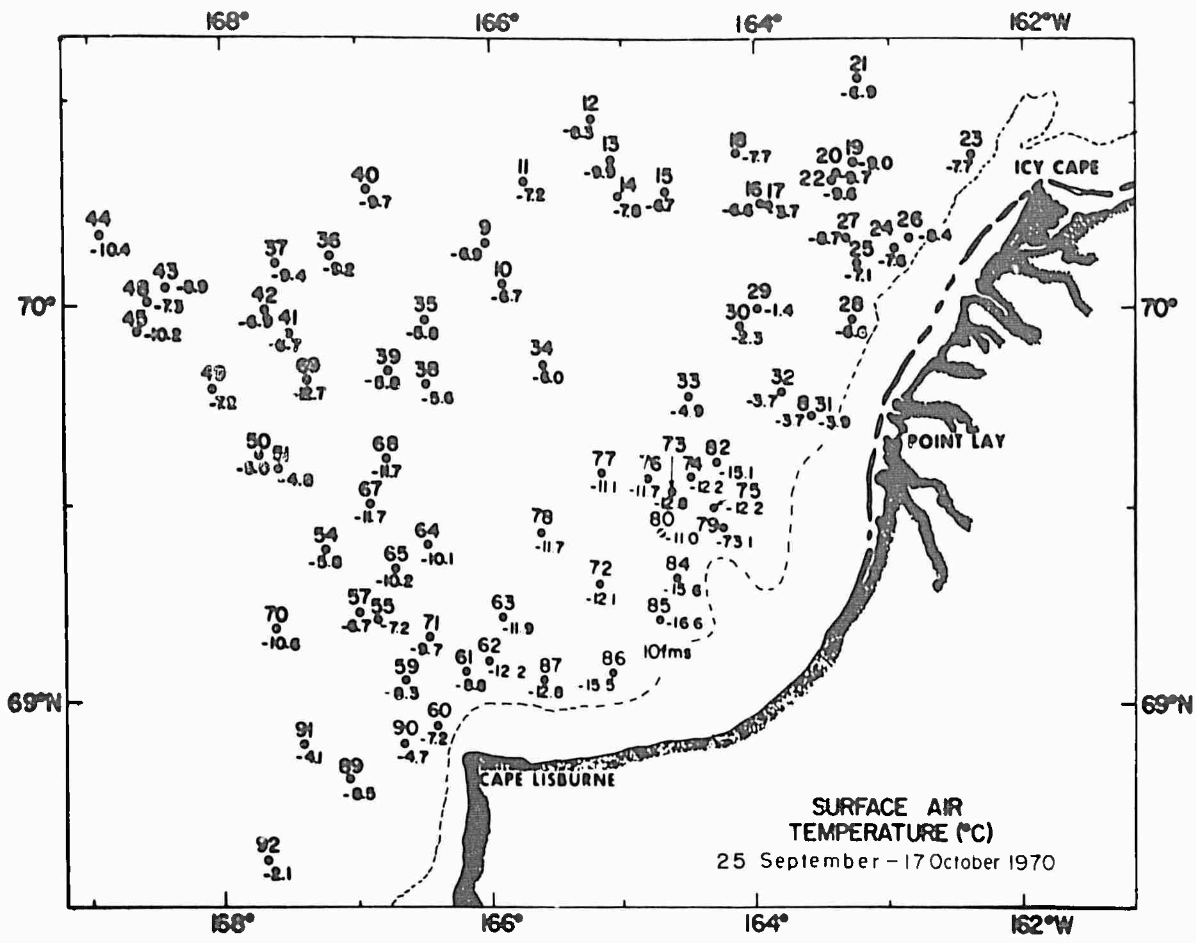


Figure 30.—Concentration of dissolved silicate (μg-at/l) near bottom during WEBSEC-70, 25 September–17 October 1970.



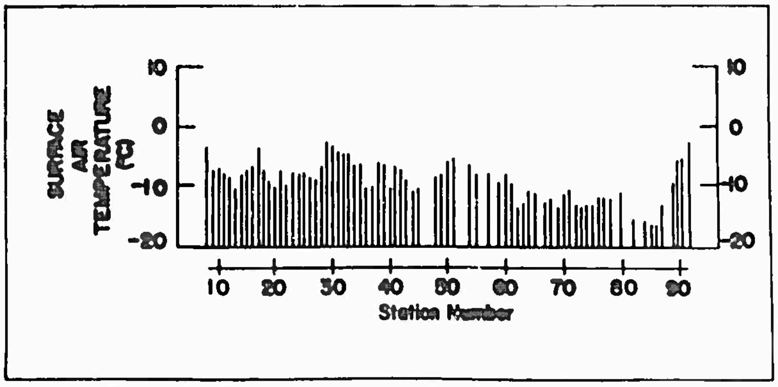
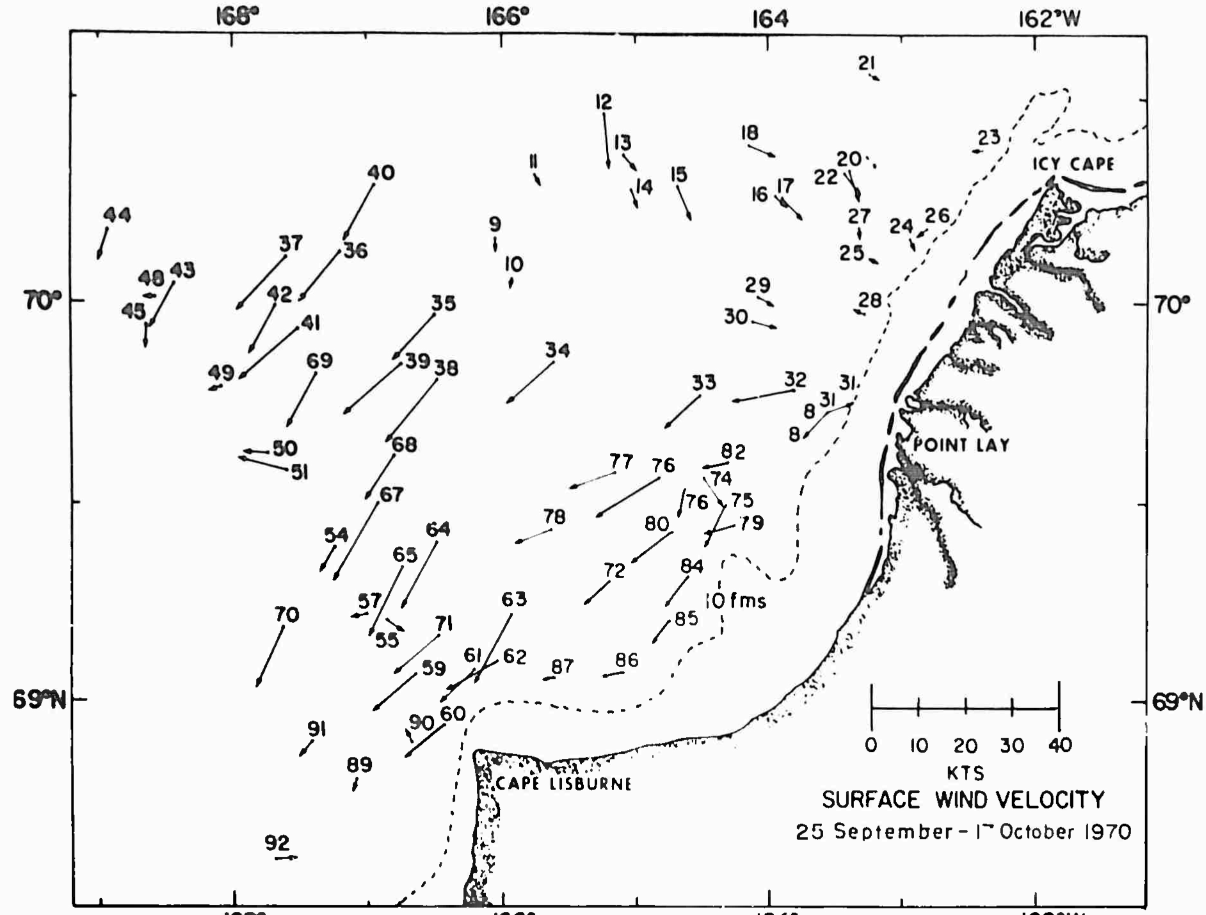


Figure 31.—Surface air temperature (°C) during WEBSEC–70, 25 September–17 October 1970.



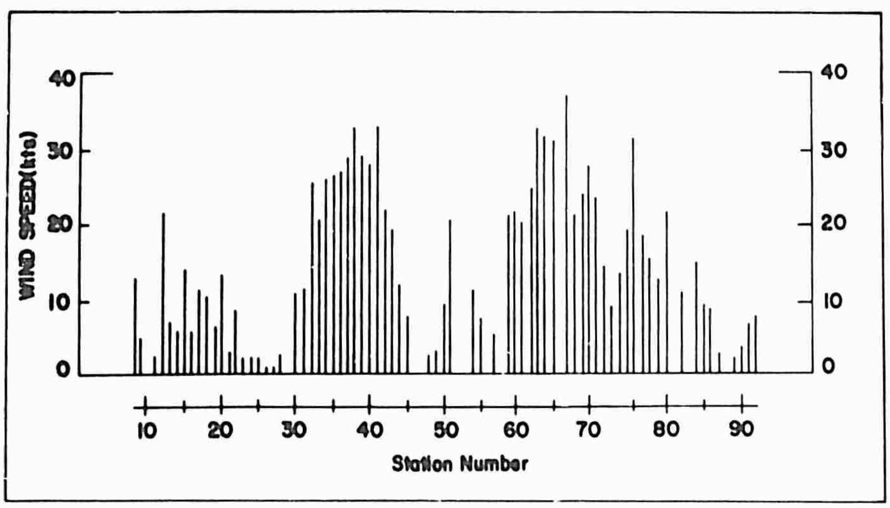


Figure 32.—Surface wind velocity during WEBSEC-70, 25 September-17 October 1970.

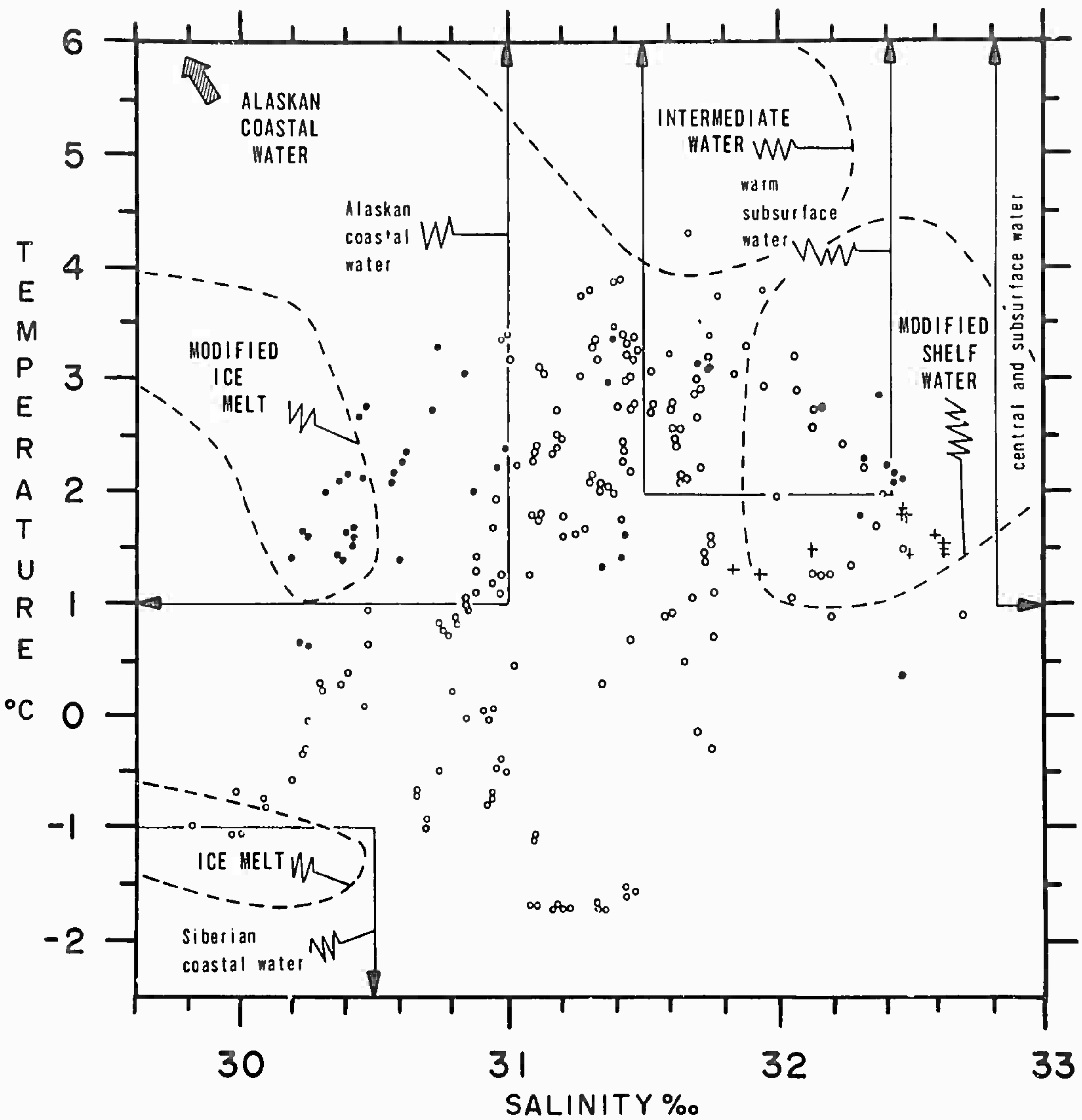


Figure 33.—Observed temperature (°C)–salinity (‰) values during WEBSEC–70 September–October 1970 (indicated by o), and NORTHWIND, October 1962 (indicated by • for Cape Lisburne-Icy Cape and + for Bering Strait >20 m) compared with water mass classifications of previous investigators (Saur, et al., 1954 indicated -------- and capital letters, and Aagaard, 1964 indicated by ——— and lower case letters).

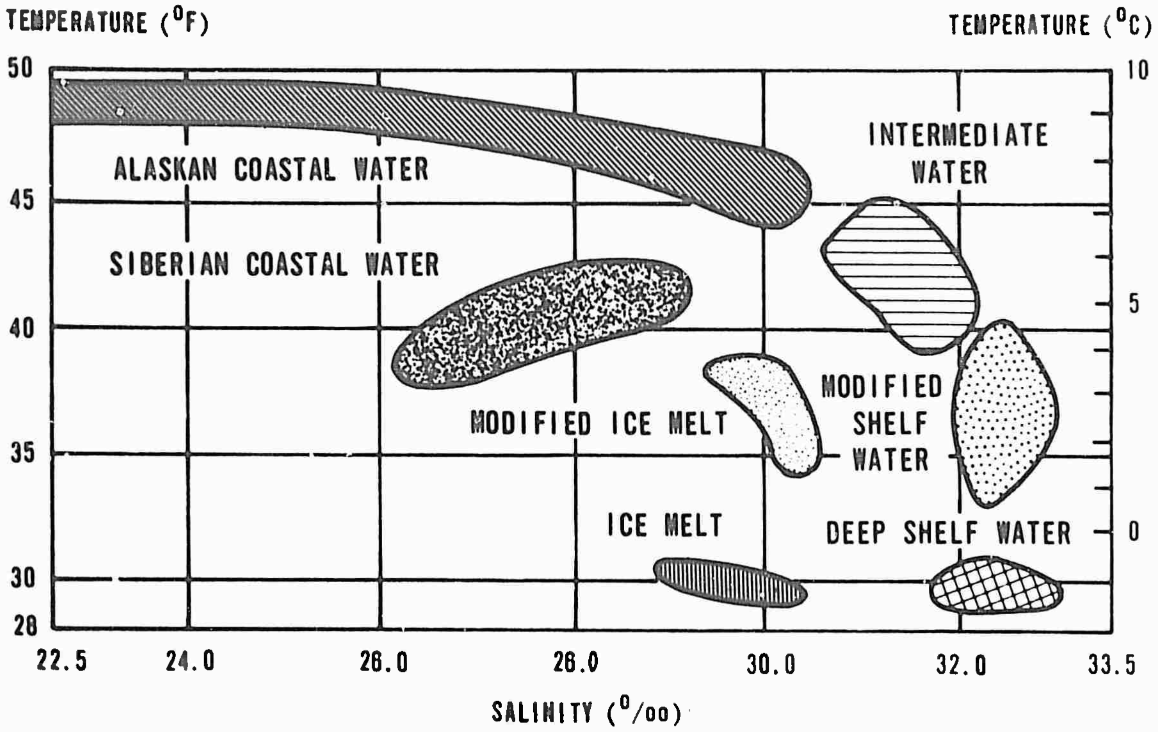


Figure 34.—Water mass classifications for the eastern Bering and Chukchi seas (from Saur, et al., 1954).

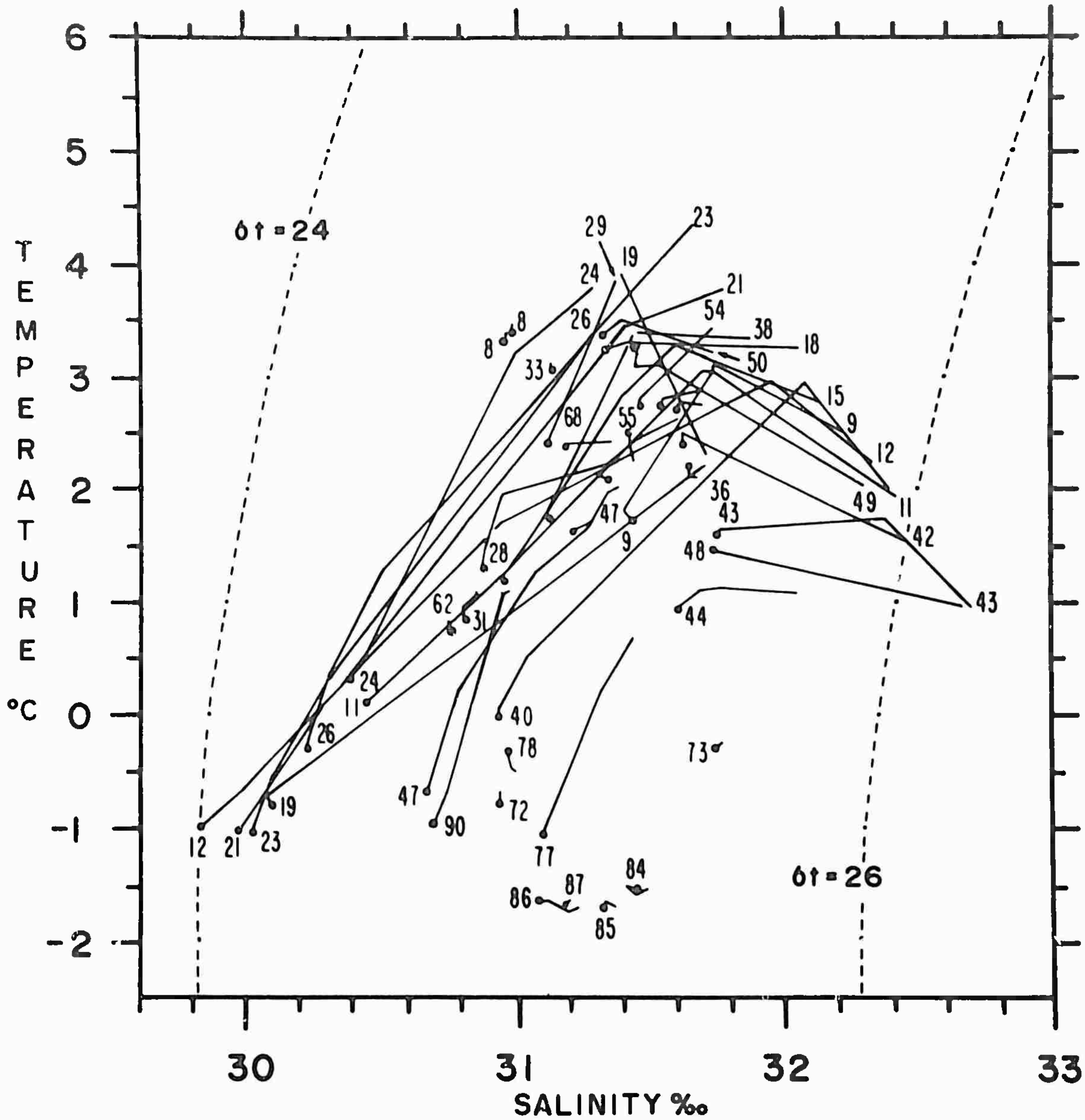


Figure 35.—Temperature (°C)—salinity (‰) regressions from WEBSEC-70 observations (25 September–17 October, 1970). Dots indicate surface values. Numbers are station numbers.

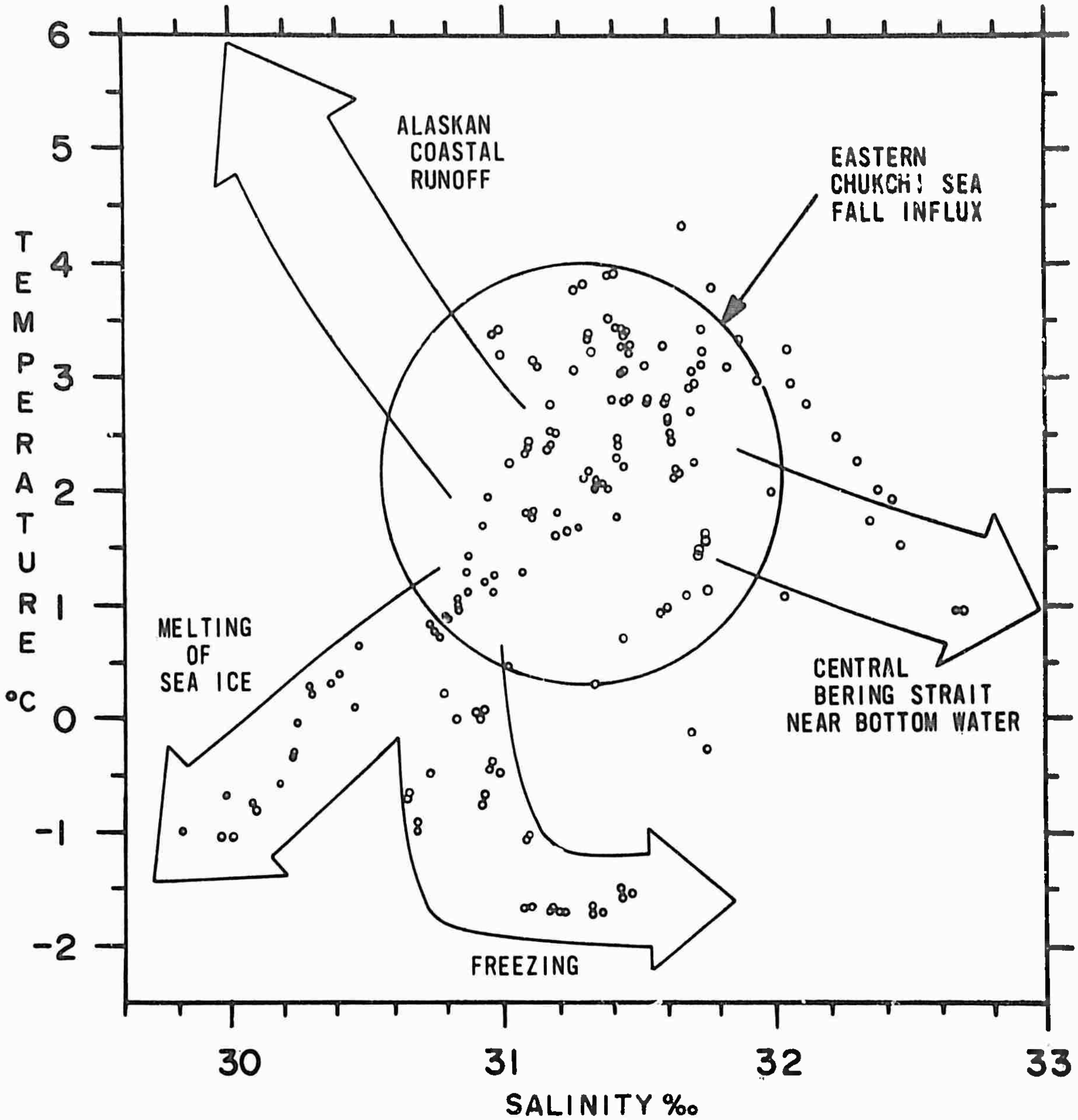


Figure 36.—Observed temperature (°C)–salinity (‰) values during WEBSEC–70, September–October 1970 and processes or water masses influencing the properties of Eastern Chukchi Sea Fall Influx.

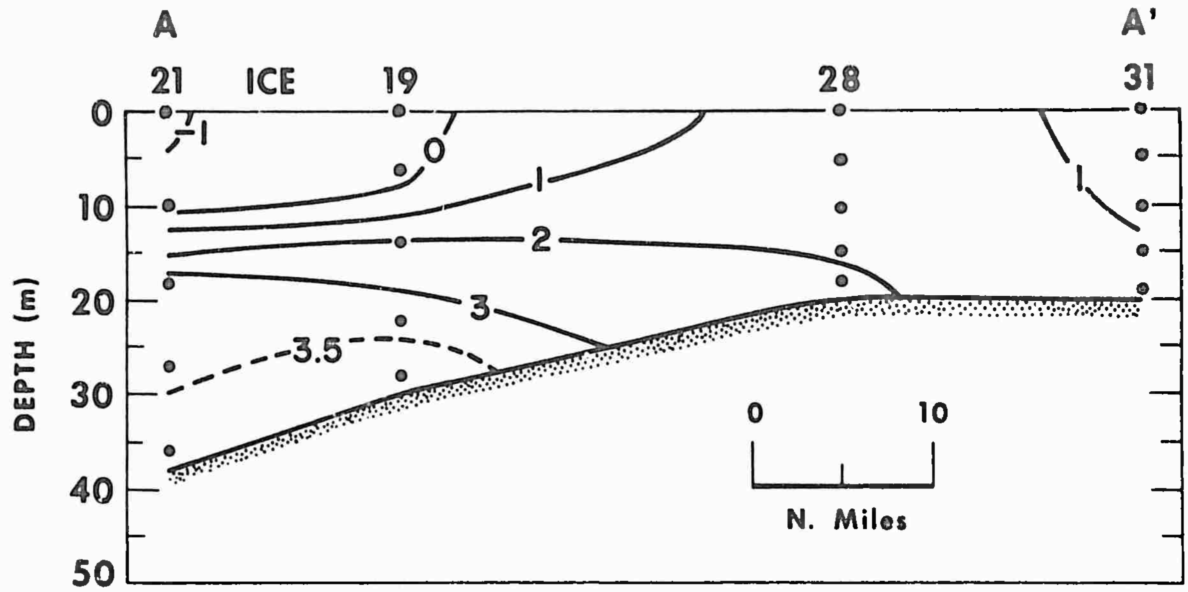


Figure 37.—Vertical profile of temperature (°C) along section A–A' (location shown in Figure 2), 1–5 October 1970, during WEBSEC–70.

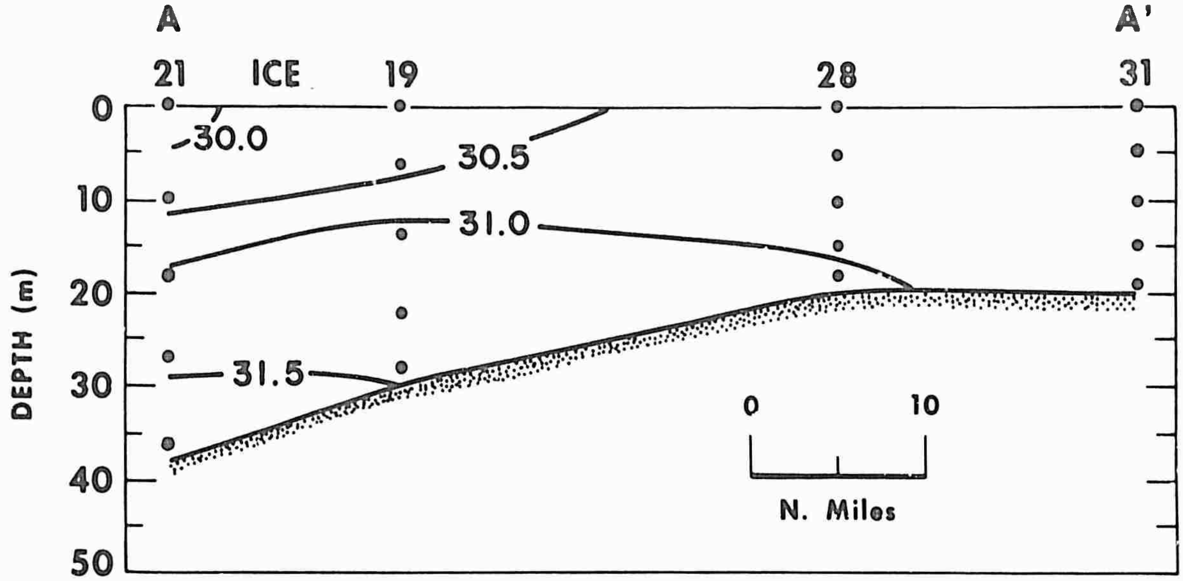


Figure 38.—Vertical profile of salinity (‰) along section A–A' (location shown in Figure 2), 1–5 October 1970, during WEBSEC–70.

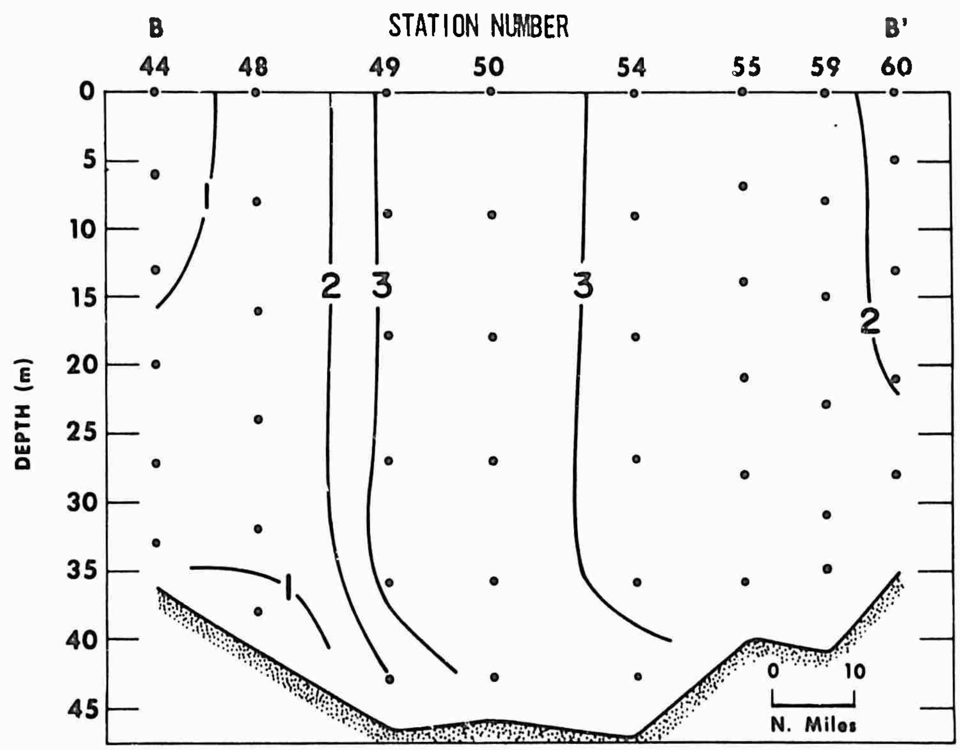


Figure 39.—Vertical profile of temperature (°C) along section B–B' (location shown in Figure 2), 8–11 October 1970, during WEBSEC–70.

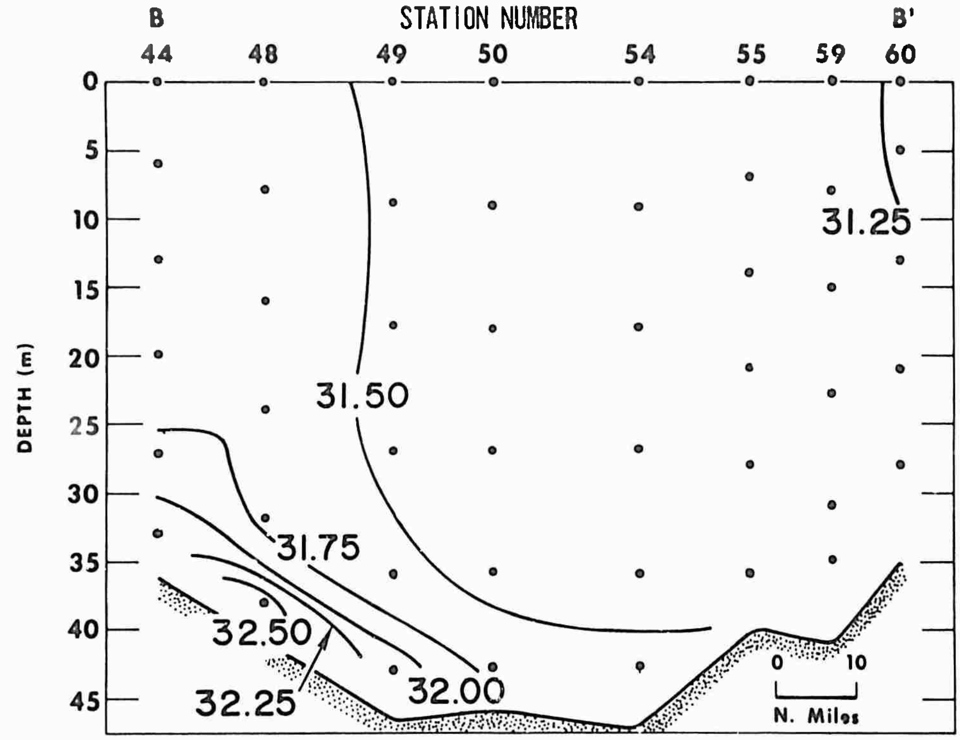


Figure 40.—Vertical profile of salinity (‰) along section B–B′ (location shown in Figure 2), 8–11 October 1970, during WEBSEC–70.

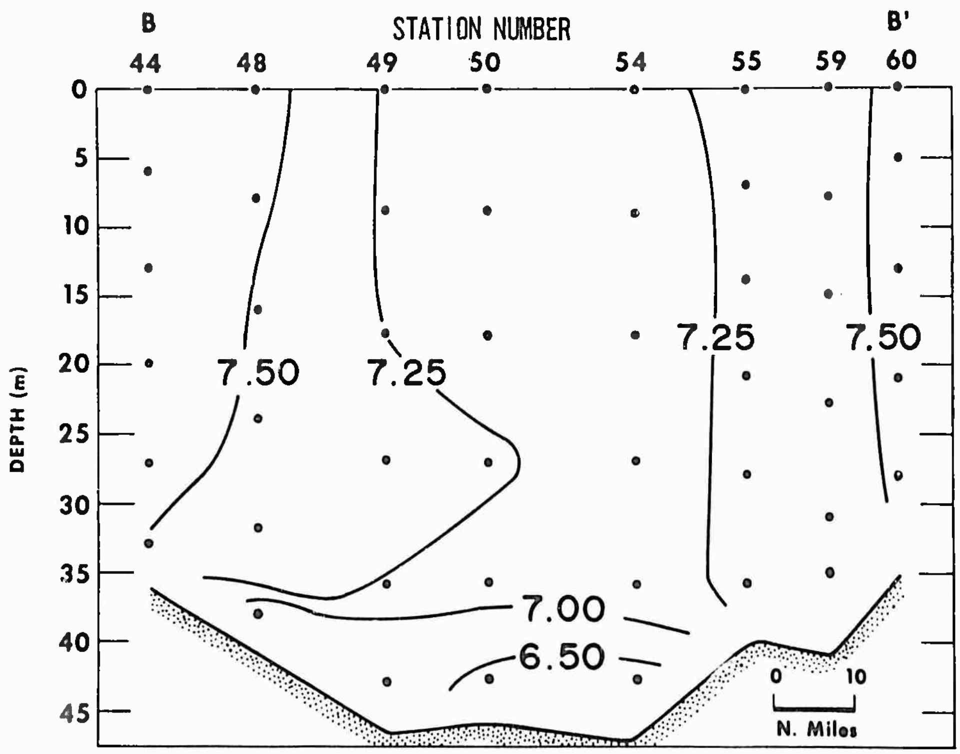


Figure 41.—Vertical profile of dissolved oxygen (ml/l) along section B–B′ (location shown in Figure 2), 8–11 October 1970, during WEBSEC–70.

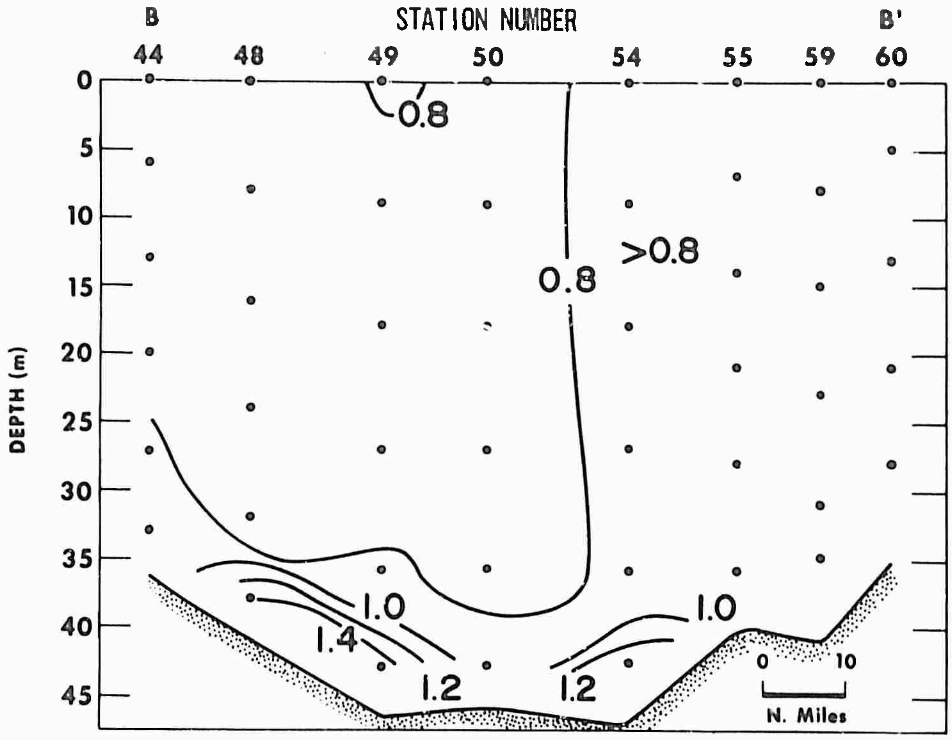


Figure 42.—Vertical profile of dissolved inorganic phosphate (μg-at/l) along section B–B' (location shown in Figure 2), 8-11 Oct ber 1970, during WEBSГC–70.

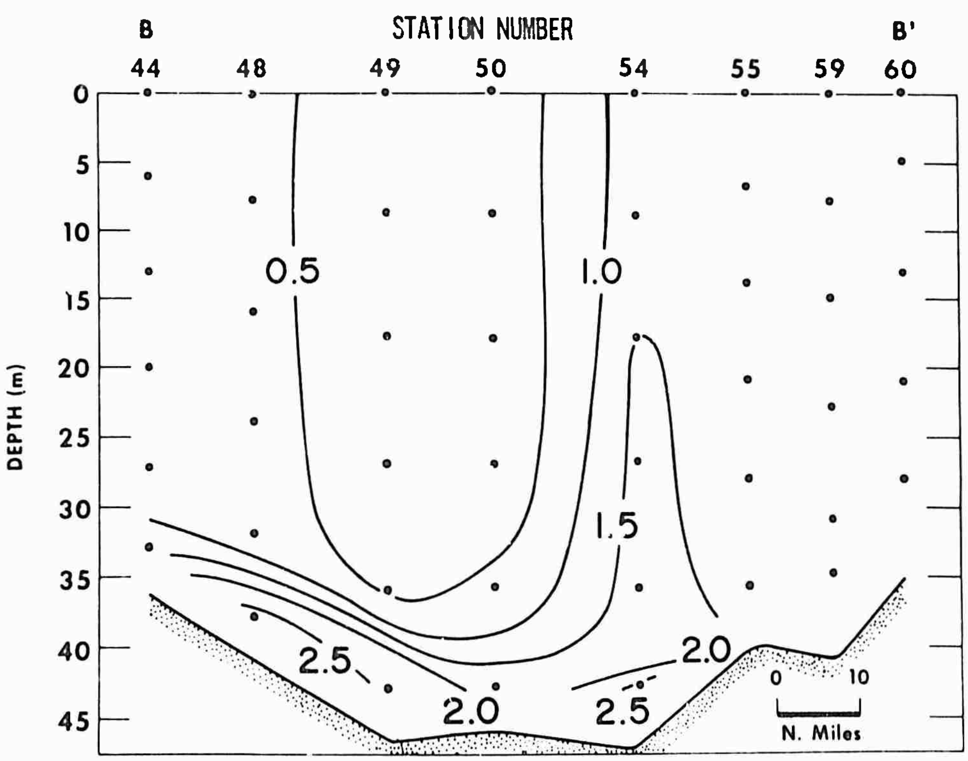


Figure 43.—Vertical profile of dissolved inorganic nitrate (μg-at/l) along section B–B' (location shown in Figure 2), 8–11 October 1970, during WEBSEC–70.

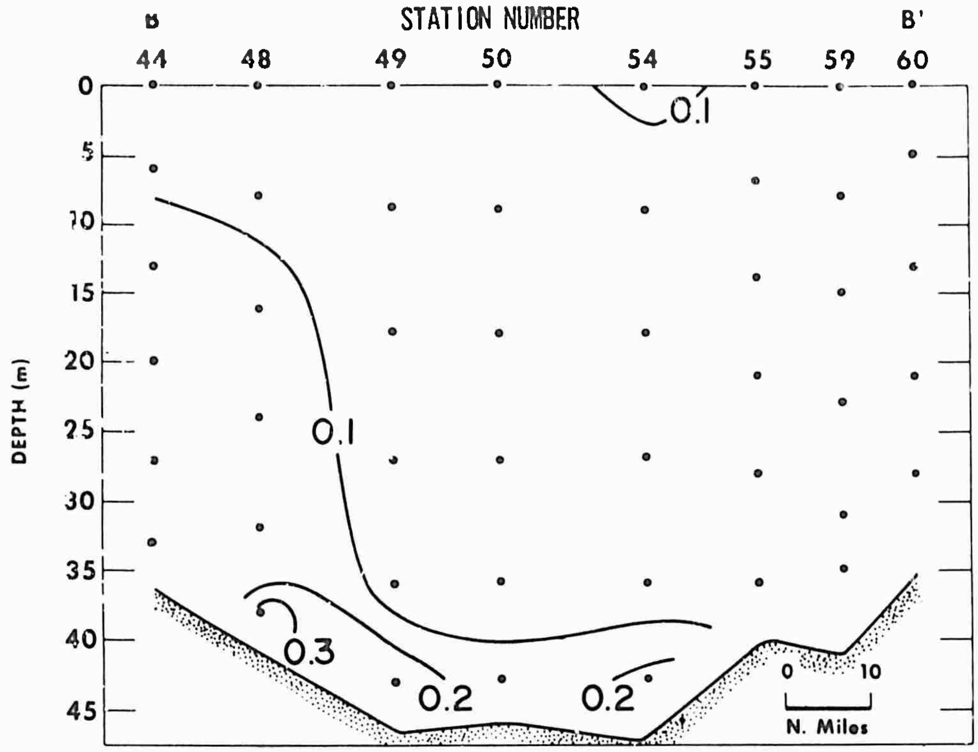


Figure 44.—Vertical profile of dissolved inorganic nitrite (μg-at/l) along section B–B' (location shown in Figure 2), 8–11 October 1970, during WEBSEC–70.

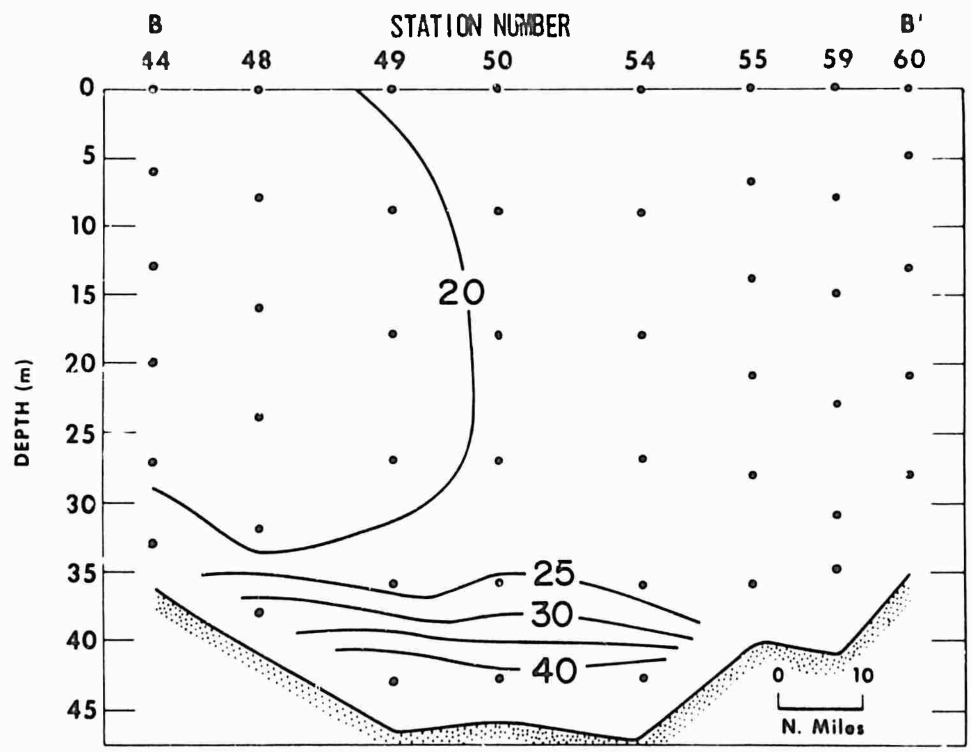


Figure 45.—Vertical profile of dissolved inorganic silicate (μg-at/l) along section B–B' (location shown in Figure 2), 8–11 October 1970, during WEBSEC–70.

STATION 8

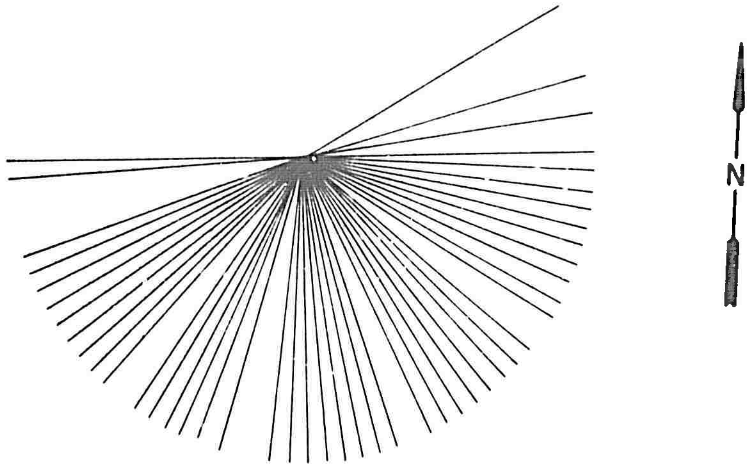


Figure 46.—Histogram of current direction measured at 10 m during a period of 31 hours on station 8, WEBSEC–70, 25 September 1970. The speed record proved to be unreliable on that station, so an arbitrary, constant speed has been assigned for display purposes. Vectors are directed away from the center of the array. Because of the length of the record, it was digitized only at 17.5-minute intervals.

STATION 26

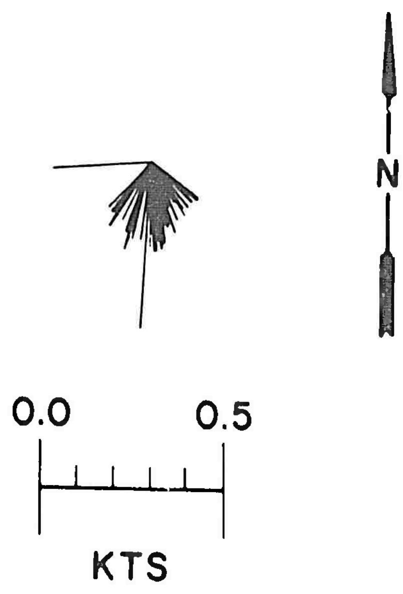


Figure 47.—Histogram of current velocities measured at 10 m during a period of 308 minutes on station 26, WEBSEC–70, 3 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

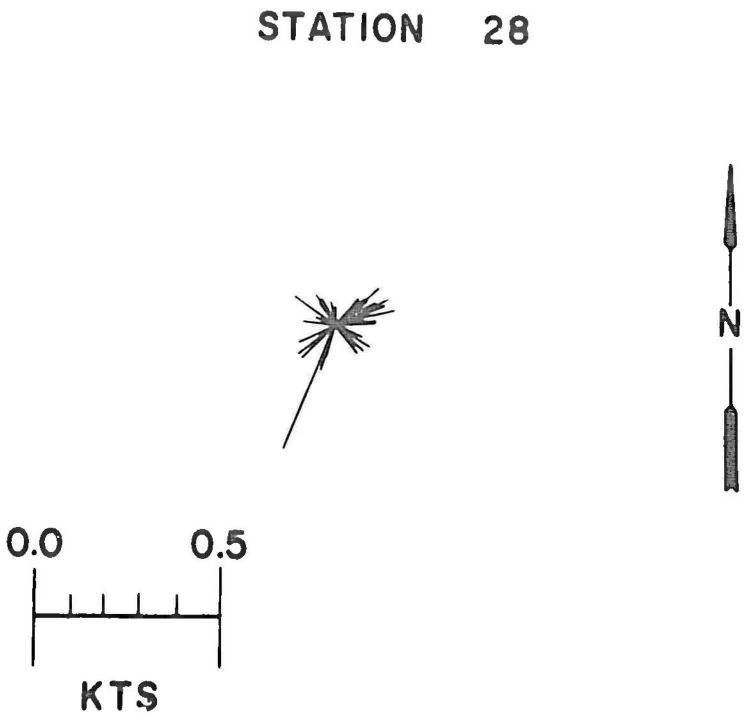


Figure 48.—Histogram of current velocities measured at 10 m during a period of 165 minutes on station 28, WEBSEC–70, 4 October 1970. Vectors are directed away from the center of the array. Record was digitized at 3.5-minute intervals.

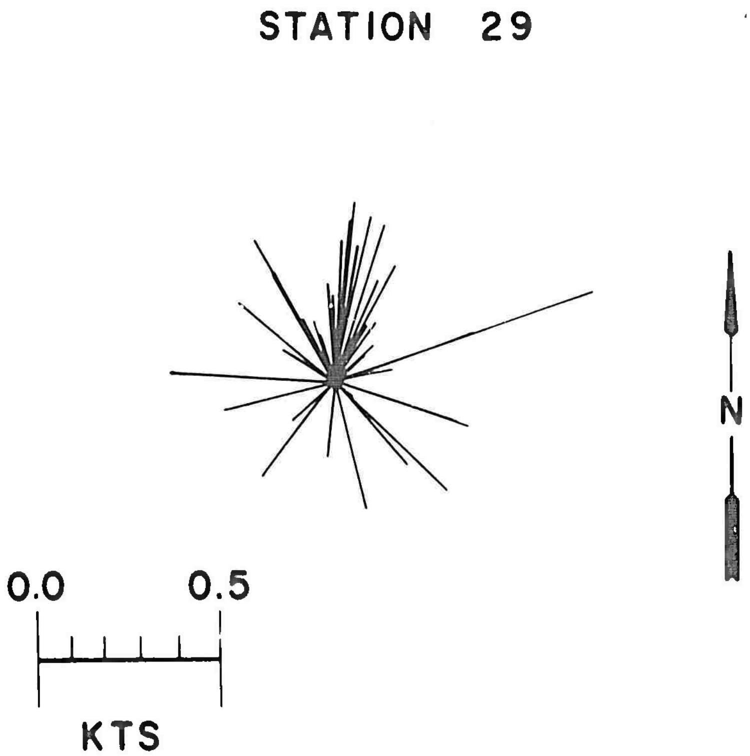


Figure 49.—Histogram of current velocities measured at 10 m during a period of 210 minutes on station 29, WEBSEC–70, 4 October 1970. Vectors are directed away from the center of the array. Record was digitized at 3.5-minute intervals.

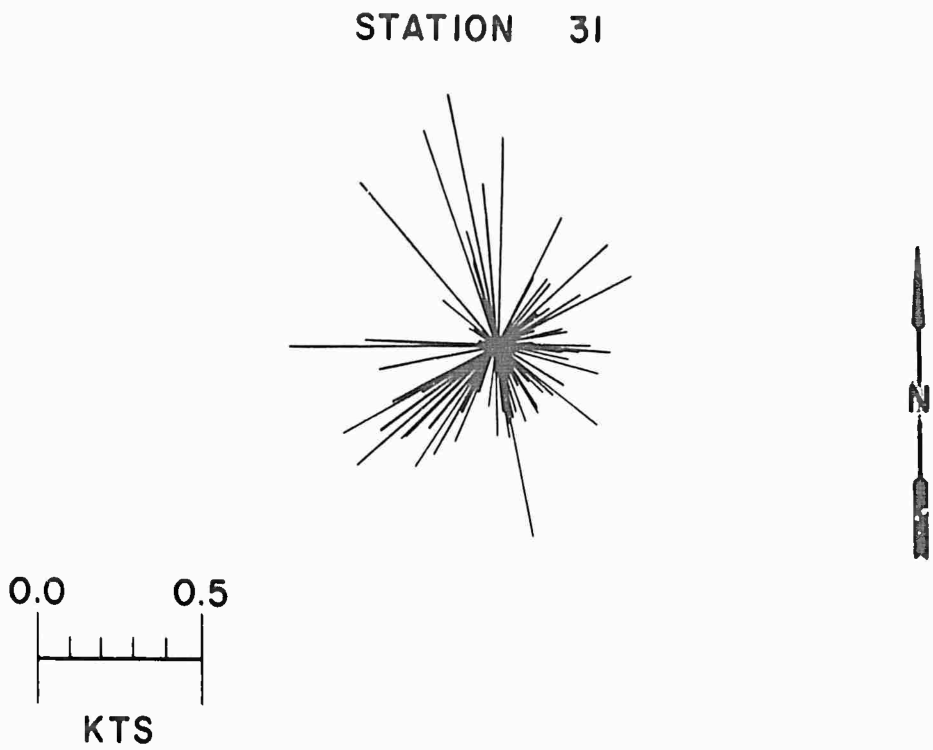


Figure 50.—Histogram of current velocities measured at 10 m during a period of 311 minutes on station 31, WEBSEC–70, 5 October 1970. Vectors are directed away from the center of the array. Record was digitized at 3.5-minute intervals.

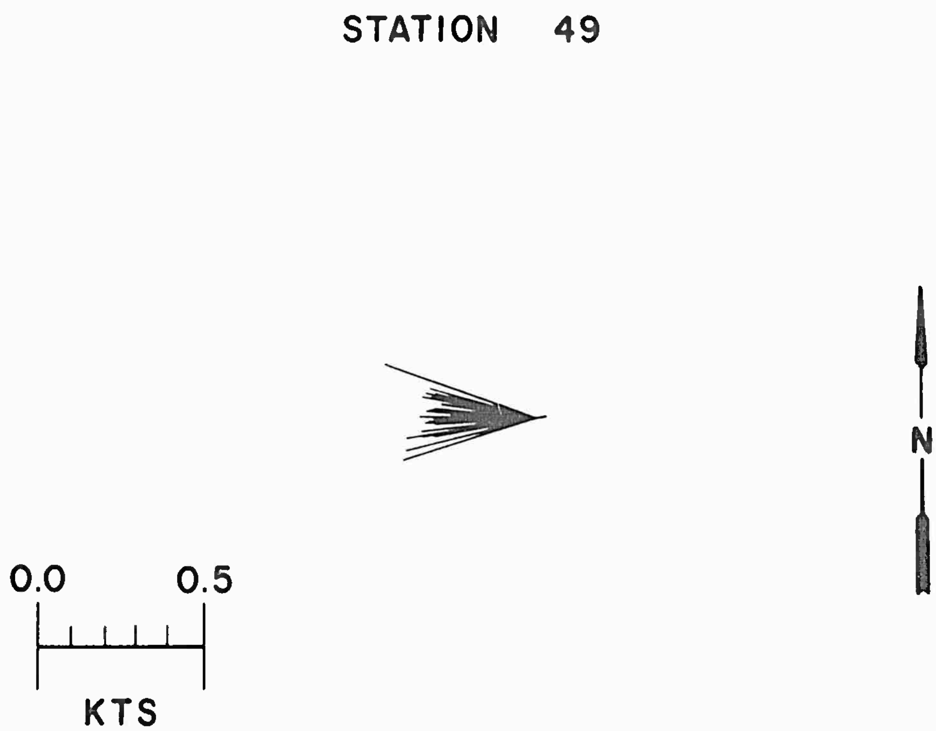


Figure 51.—Histogram of current velocities measured at 10 m during a period of 164 minutes on station 49, WEBSEC–70, 9 October. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

STATION 50

Figure 52.—Histogram of current velocities measured at 10 m during a period of 200 minutes on station 50, WEBSEC–70, 9 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

STATION 54

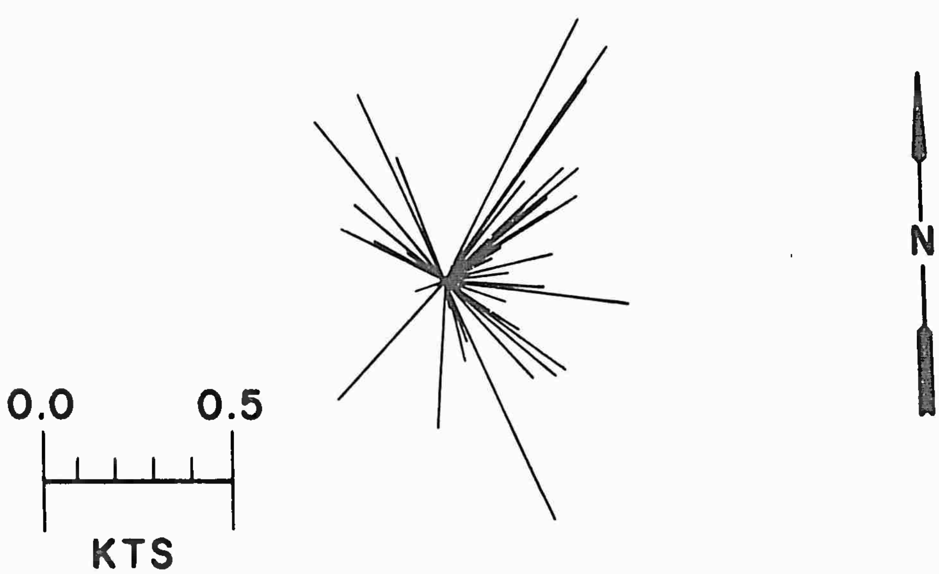


Figure 53.—Histogram of current velocities measured at 10 m during a period of 126 minutes on station 54, WEBSEC–70, 10 October 1970. Vectors are directed away from the center of the array. Record was digitized at 3.5-minute intervals.

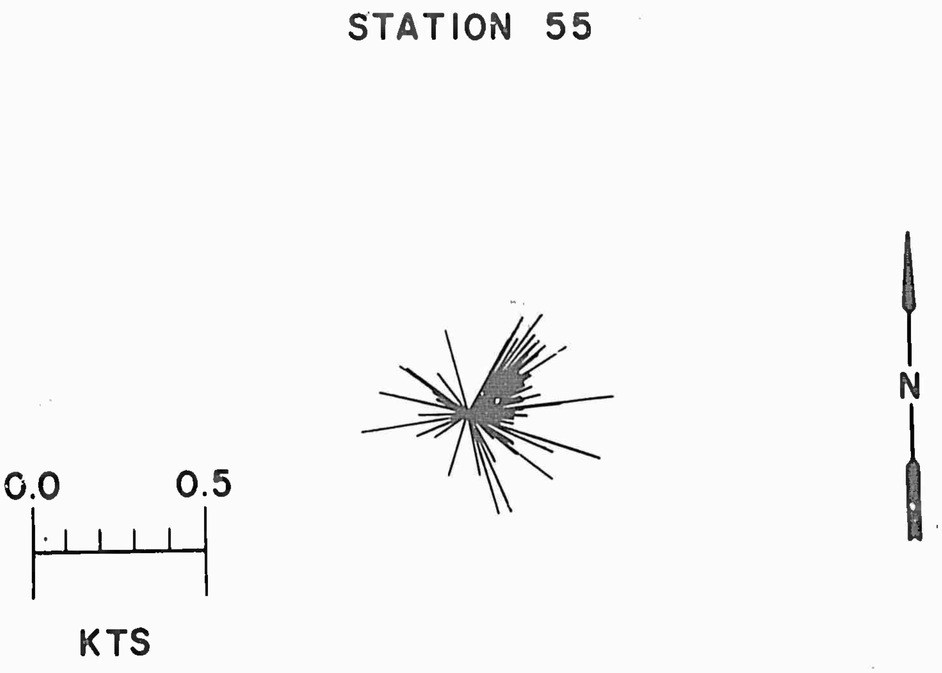


Figure 54.—Histogram of current velocities measured at 10 m during a period of 385 minutes on station 55, WEBSEC–70, 10 October 1970. Vectors are directed away from the center of the array. Record was digitized at 3.5-minute intervals.

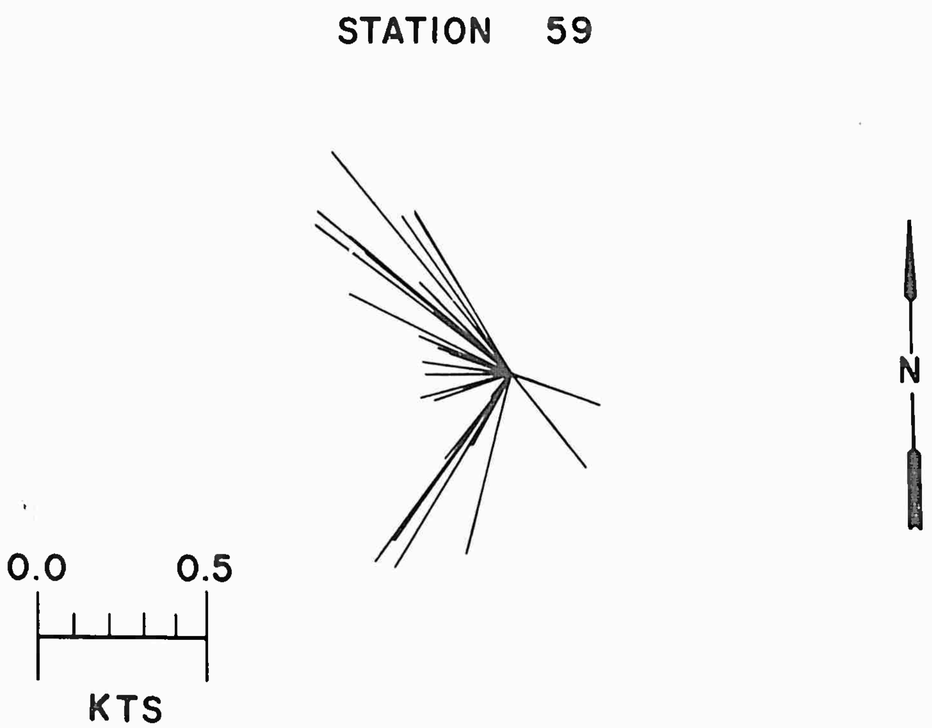


Figure 55.—Histogram of current velocities measured at 10 m during a period of 123 minutes on station 59, WEBSEC–70, 11 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

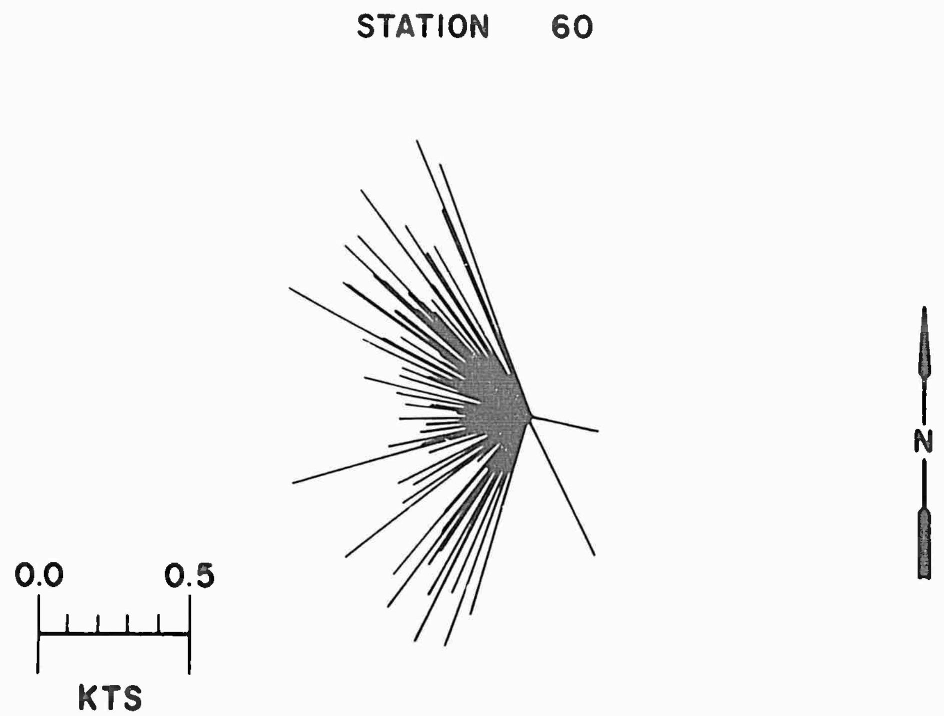


Figure 56.—Histogram of current velocities measured at 10 m during a period of 329 minutes on station 60, WEBSEC–70, 11 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

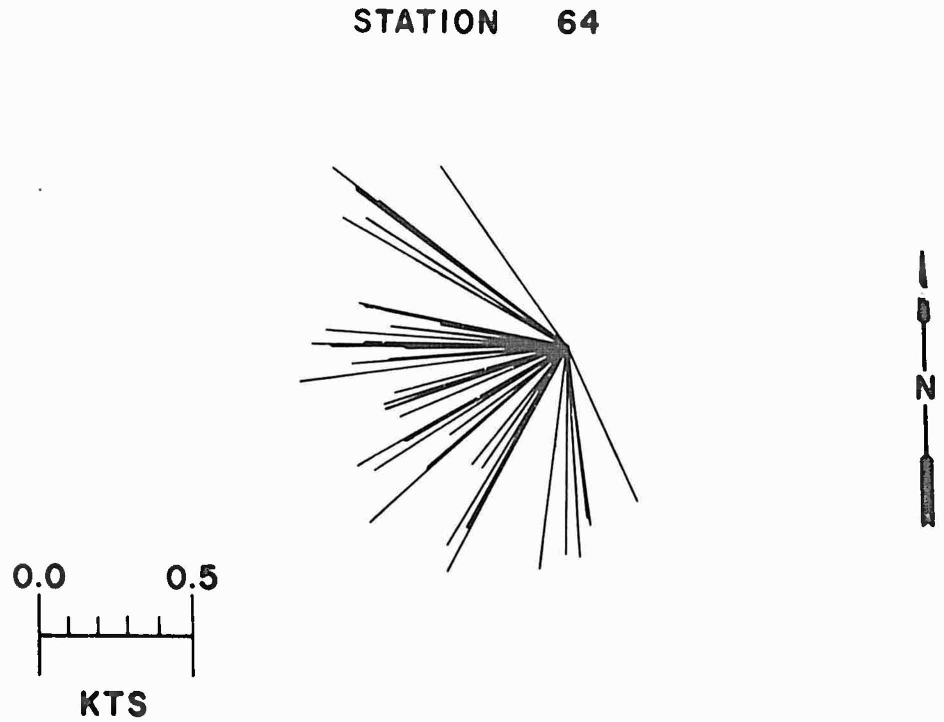


Figure 57.—Histogram of current velocities measured at 10 m during a period of 148 minutes on station 64, WEBSEC–70, 12 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

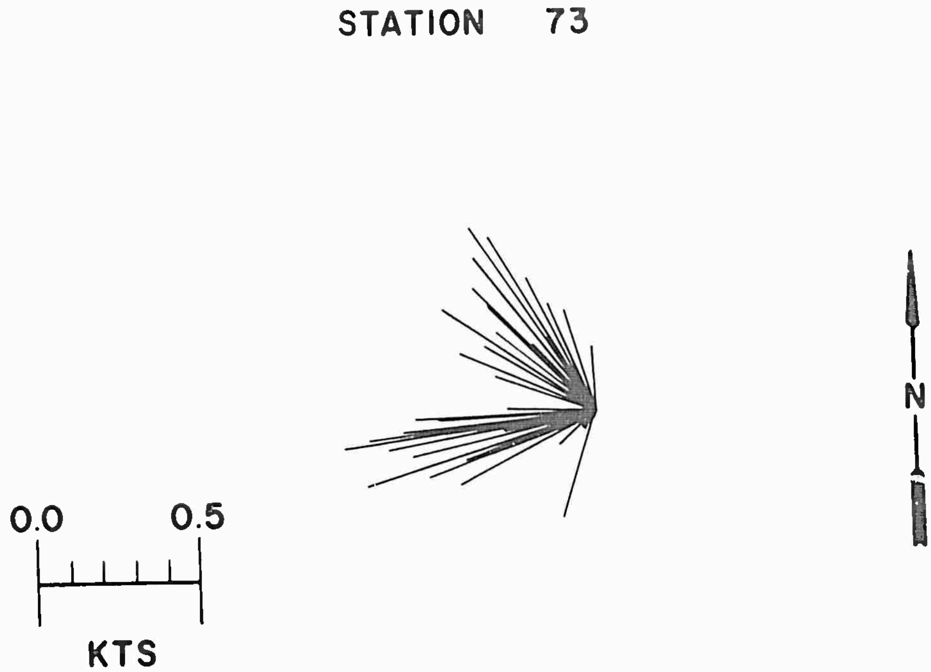


Figure 58.—Histogram of current velocities measured at 10 m during a period of 206 minutes on station 73, WEBSEC–70, 14 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

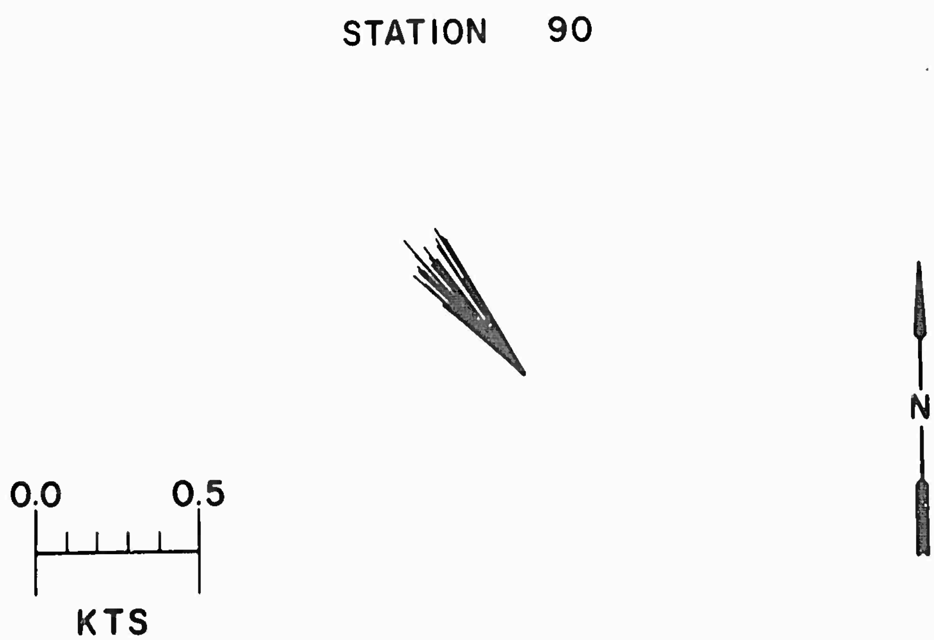


Figure 59.—Histogram of current velocities measured at 10 m during a period of 144 minutes on station 90, WEBSEC–70, 17 October 1970. Vectors are directed away from the apex of the array. Record was digitized at 3.5-minute intervals.

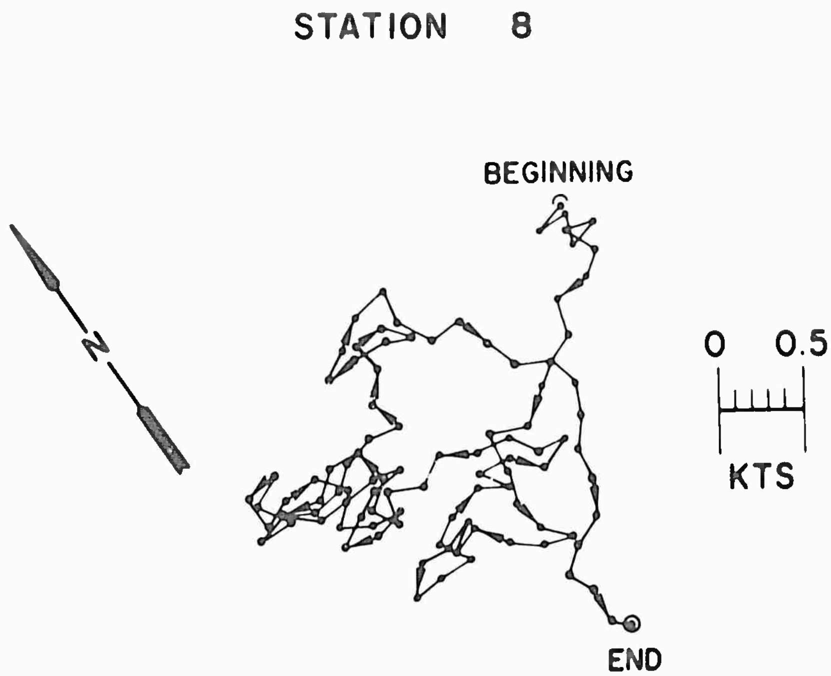


Figure 60.—Progressive vector diagram for currents at 10 m during period of 31 hours on station 8, WEBSEC–70, 25 September 1970. The speed record proved to be unreliable on that station, so an arbitrary, constant speed has been assigned for display purposes. Because of the length of the record, it was digitized only at 17.5-minute intervals.

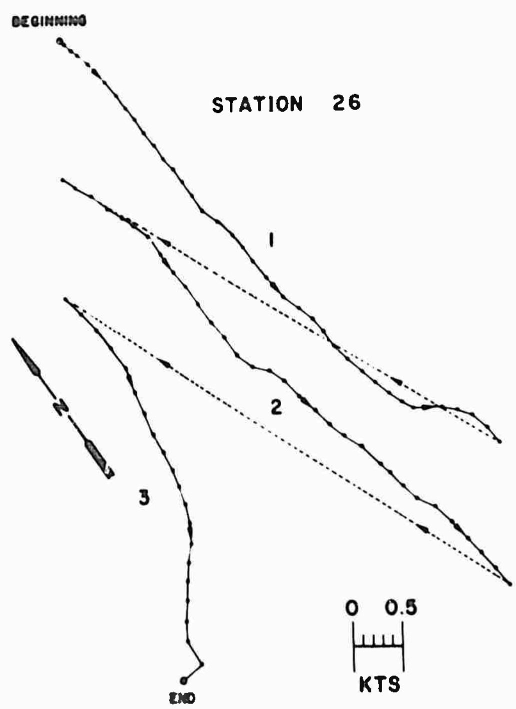


Figure 61.—Progressive vector diagram for currents at 10 m during a period of 308 minutes on station 26, WEBSEC–70, 3 October 1970. Record was digitized at 3.5-minute intervals.

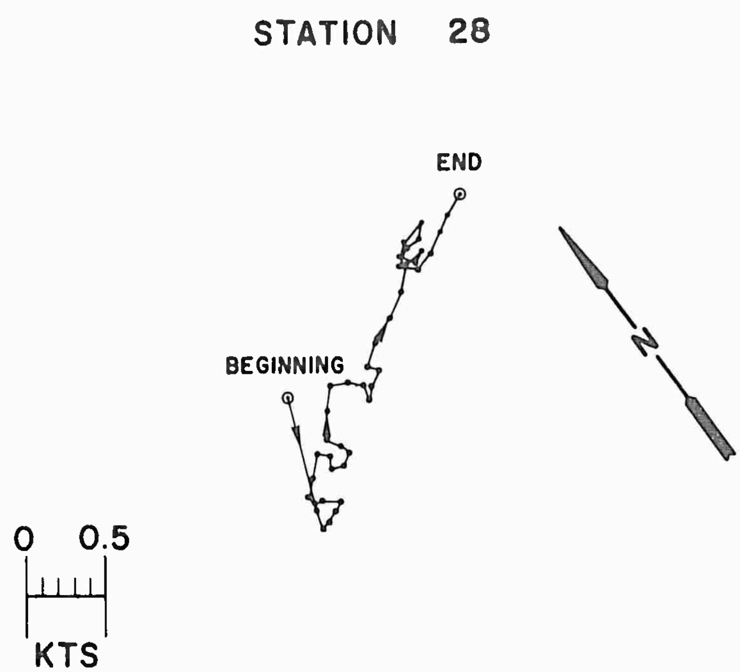


Figure 62.—Progressive vector diagram for currents at 10 m during a period of 165 minutes on station 28, WEBSEC–70, 4 October 1970. Record was digitized at 3.5-minute intervals.

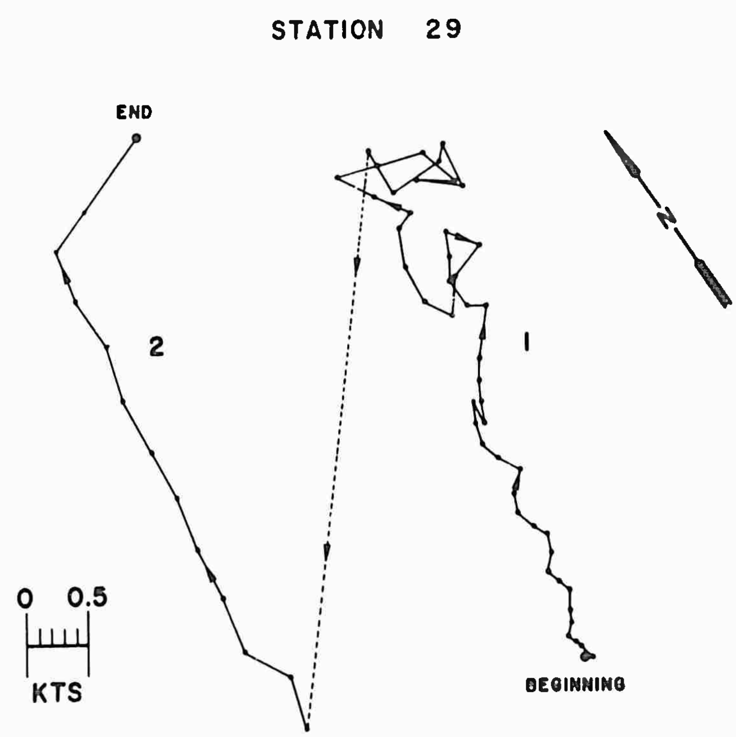


Figure 63.—Progressive vector diagram for currents at 10 m during a period of 210 minutes on station 29, WEBSEC–70, 4 October 1970. Record was digitized at 3.5-minute intervals.

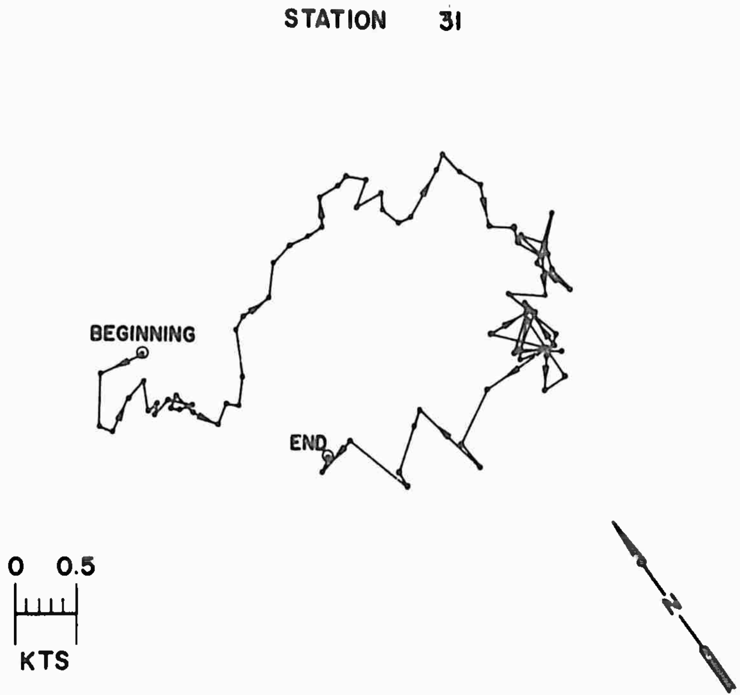


Figure 64.—Progressive vector diagram for currents at 10 m during a period of 311 minutes on station 31, WEBSEC–70, 5 October 1970. Record was digitized at 3.5-minute intervals.

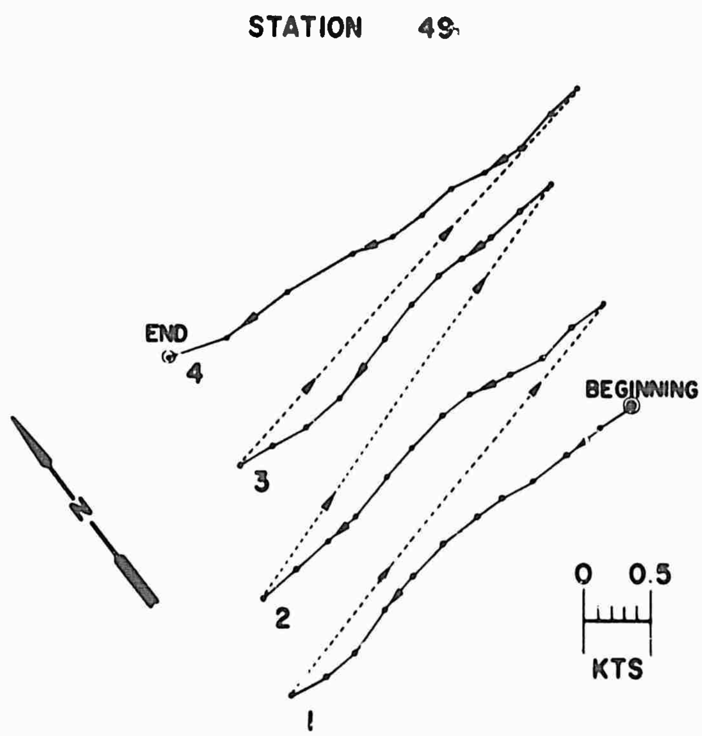


Figure 65.—Progressive vector diagram for currents at 10 m during a period of 164 minutes on station 49, WEBSEC–70, 9 October 1970. Record was digitized at 3.5-minute intervals.

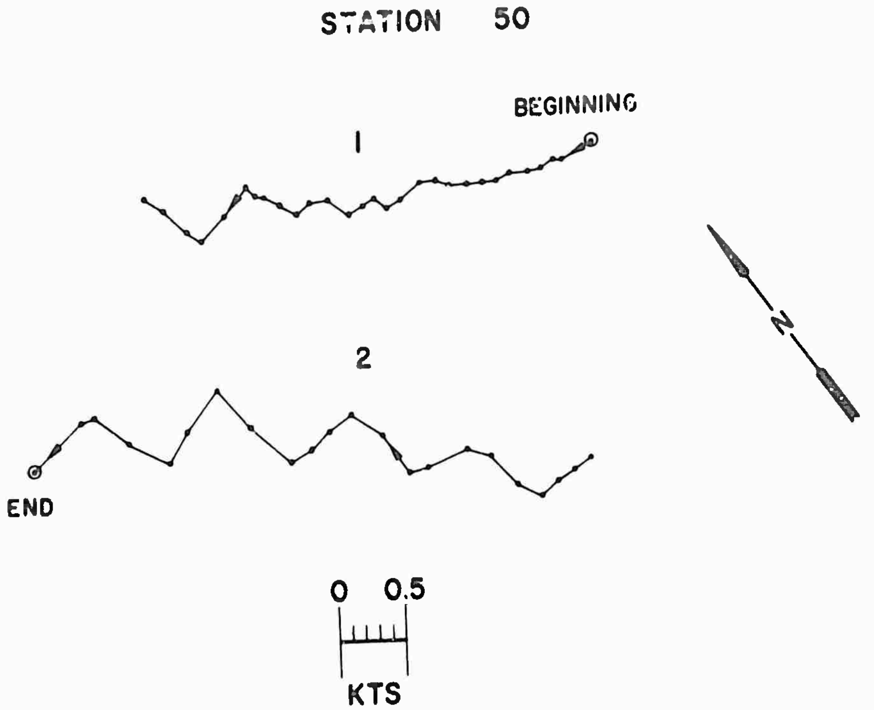


Figure 66.—Progressive vector diagram for currents at 10 m during a period of 200 minutes on station 50, WEBSEC–70, 9 October 1970. Record was digitized at 3.5-minute intervals.

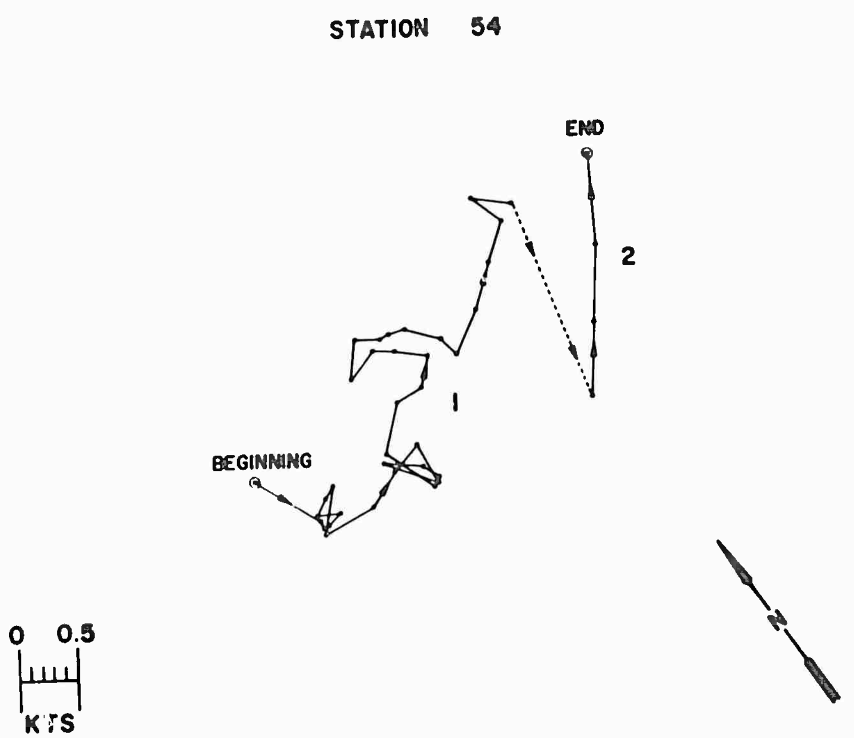


Figure 67.—Progressive vector diagram for currents at 10 m during a period of 126 minutes on station 54, WEBSEC–70, 10 October 1970. Record was digitized at 3.5-minute intervals.

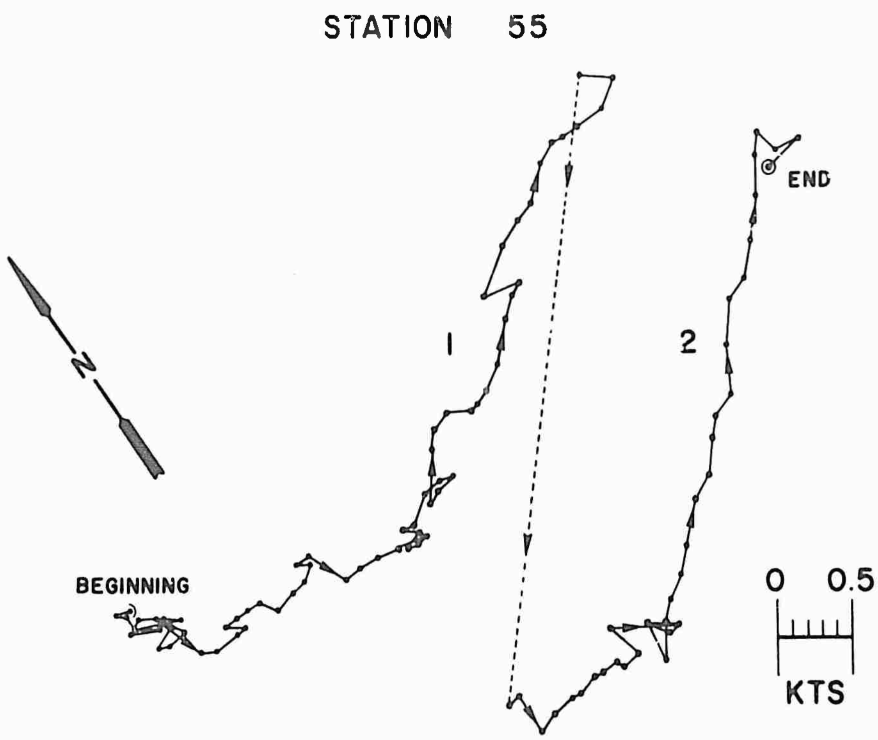


Figure 68.—Progressive vectory diagram for currents at 10 m during a period of 385 minutes on station 55, WEBSEC–70, 10 October 1970. Record was digitized at 3.5-minute intervals.

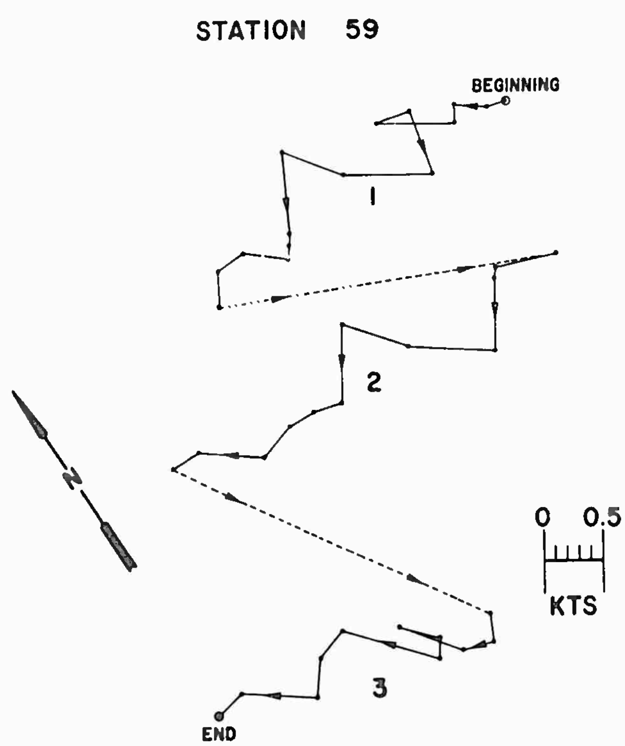


Figure 69.—Progressive vector diagram for currents at 10 m during a period of 123 minutes on station 59, WEBSEC–70, 11 October 1970. Record was digitized at 3.5-minute intervals.

STATION 60

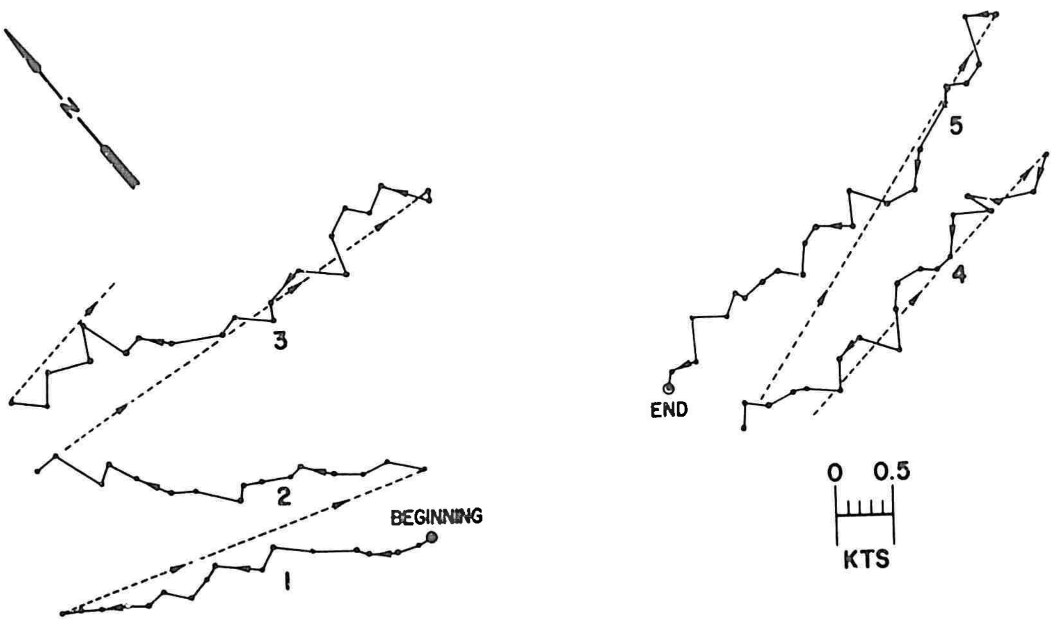


Figure 70.—Progressive vector diagram for currents at 10 m during a period of 329 minutes on station 60, WEBSEC-70, 11 October 1970. Record was digitized at 3.5-minute intervals.

STATION 64

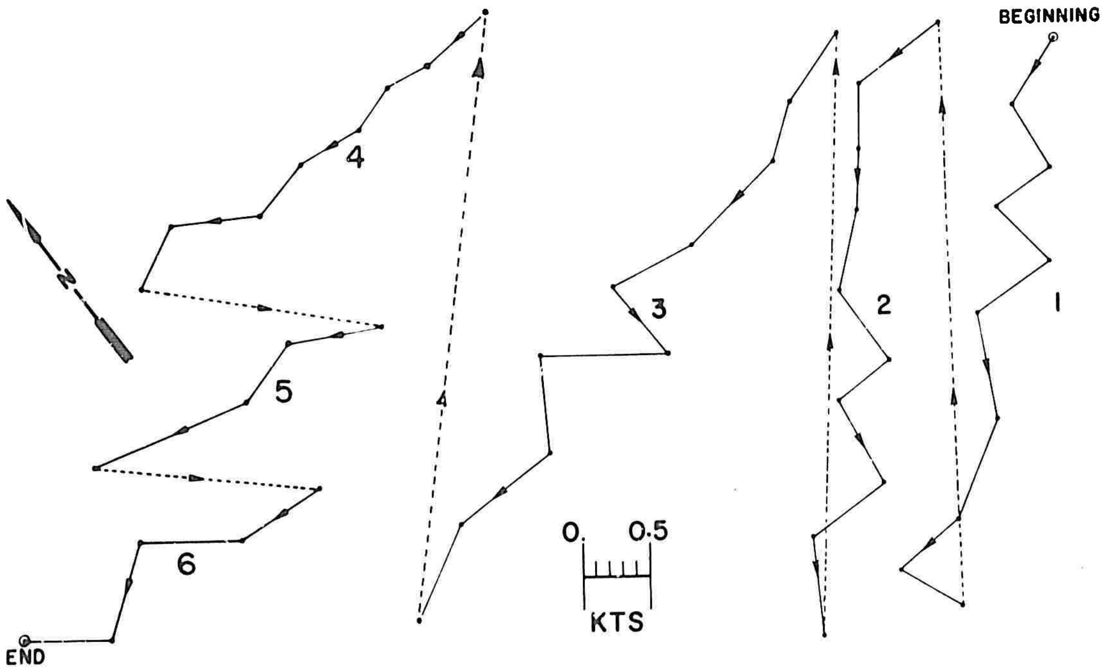


Figure 71.—Progressive vector diagram for currents at 10 m during a period of 148 minutes on station 64, WEBSEC-70, 12 October 1970. Record was digitized at 3.5-minute intervals.

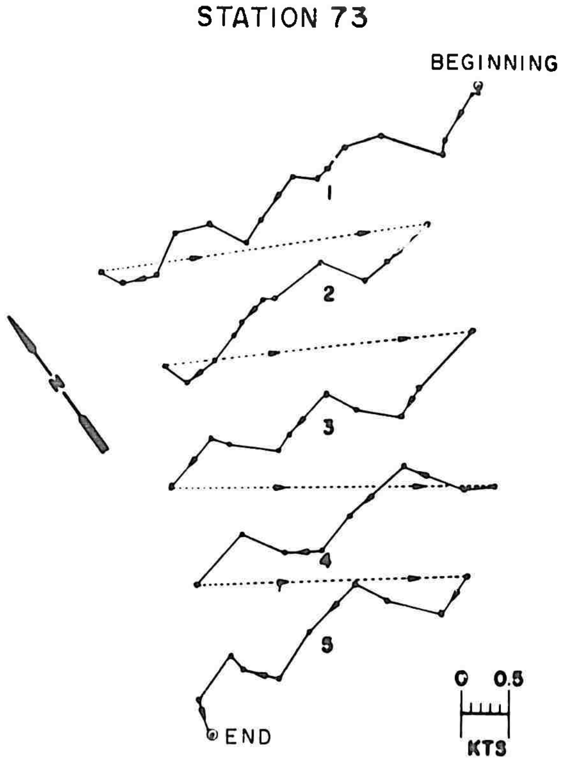


Figure 72.—Progressive vector diagram for currents at 10 m during a period of 206 minutes on station 73, WEBSEC–70, 14 October 1970. Record was digitized at 3.5-minute intervals.

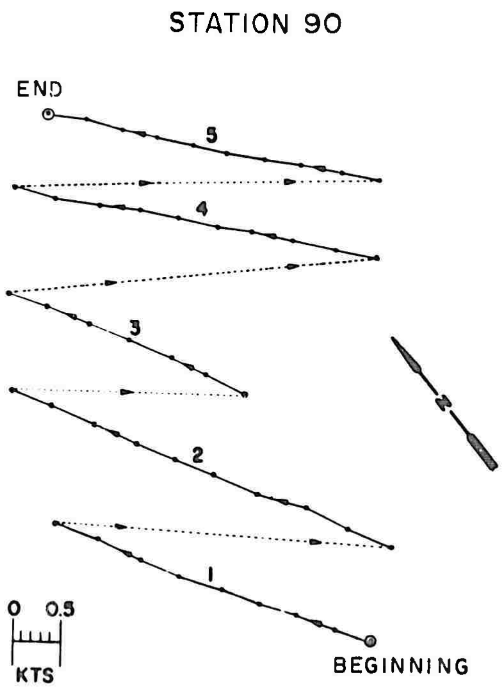


Figure 73.—Progressive vector diagram for currents at 10 m during a period of 144 minutes on station 90, WEBSEC–70, 17 October 1970. Record was digitized at 3.5-minute intervals.

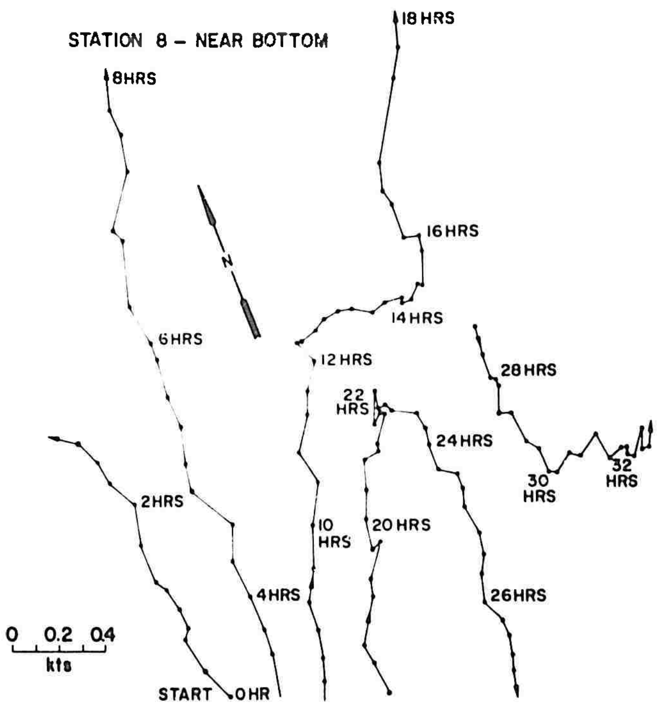


Figure 74.—Progressive vector diagram for currents near bottom during a period of 33 hours on station 8, WEBSEC–70, 25 September 1970. Vectors represent 15-minute averages.

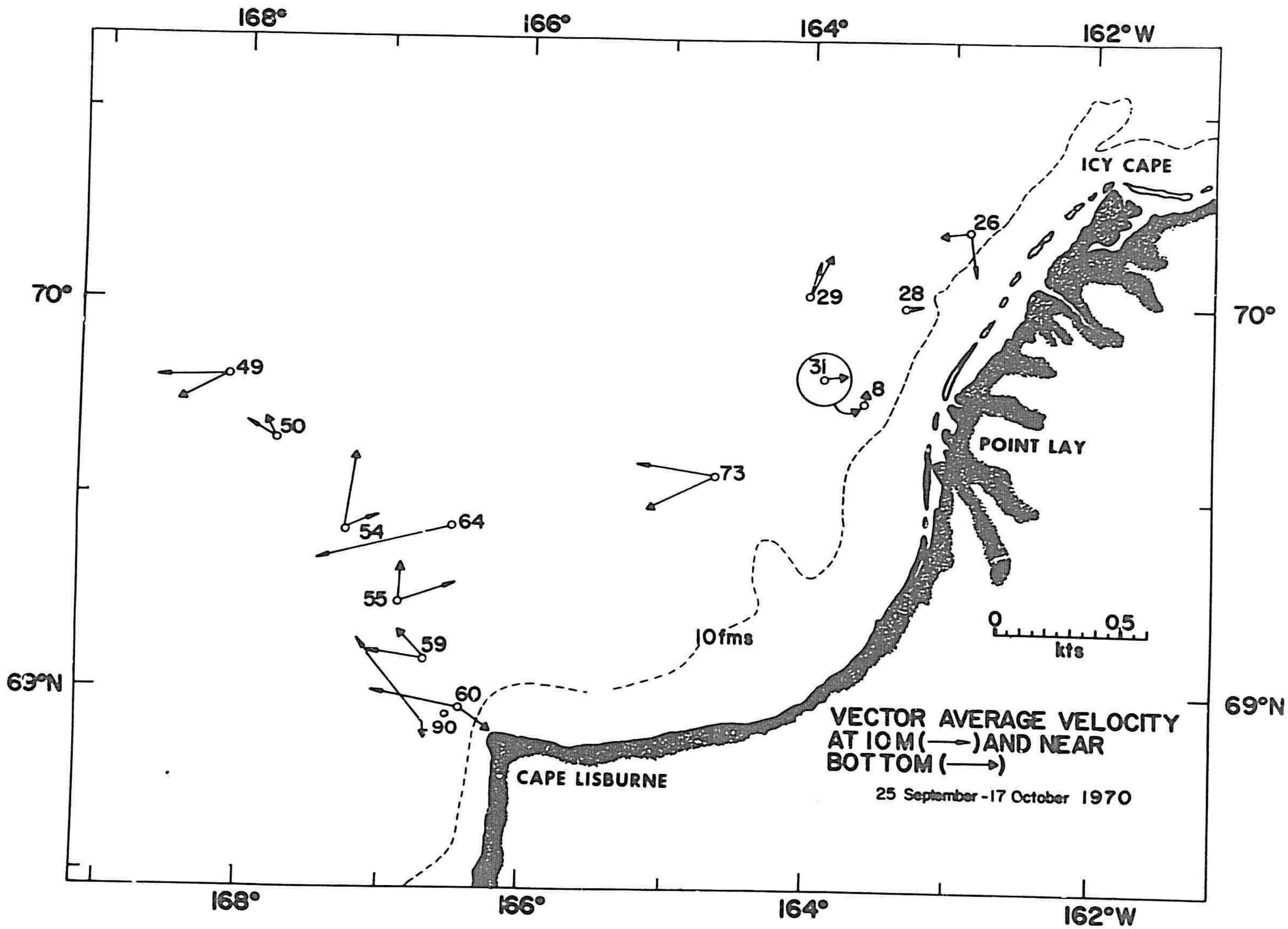


Figure 75.—Vector average velocities at 10 m and near bottom, WEBSEC–70, 25 September–17 October 1970.

Appendix A.—Oceanographic Data

Cruises listed:

Codes utilized:

A complete description of the codes utilized in the tabulation of oceanographic station data can be found in National Oceanographic Data Center publication M-2, *Processing Physical and Chemical Data from Oceanographic Stations.* (Rev. August 1964, supplement issued May 1966.)

To facilitate use of the oceanographic station data listing, entry headings which are not self-explantory are described below.

Depth to bottom ---- Corrected or uncorrected sounding in meters.
Max. depth of samples ---- Depth of deepest sample to nearest multiple of 100 meters.
Wave observations:

Dir. ---- Rounded to nearest multiple of 10 degress.

Hgt. ---- In increments of ½ m. Sum of 5 meters plus increments of ½ m. if 50 is added to direction.

Per. ---- If numerals 2 through 9 are entered, period in seconds is twice the numeric entry or 2X (numeric entry) +1. For other entries see WMO code 3155.

Sea ---- Sea state according to WMO code 3700.

Weather code ---- If preceded by X, weather according to WMO code 4501. If a two-digit entry, weather according to WMO code 4677.

Cloud code:

Type ---- Cloud type according to WMO code 0500.

Amount ---- Cloud amount in eighths. Entry of the numeral 9 indicates cloud amount could not be estimated.

Water:

Color code ---- Color according to Forel-Ule scale.

Trans. ---- Transparency in whole meters as determined by Secchi disc.

Wind:

Dir. ---- Rounded to nearest multiple of 10 degrees.

Speed or force ---- If preceded by letter S, wind speed in knots; if preceded by letter F, wina force according to Beaufort scale.

Barometer ---- Barometric pressure given in 10, units and tenths of millibars.

Air temp. °C. ---- Air temperature to tenths of a degree celsius.

Vis. code ---- Visibility according to WMO code 4300.

No. obs. depths ---- Number of observed levels associated with the station.

Messenger time ---- Entered in hours and tenths of an hour GMT. For Nansen casts, indicates time of release of messenger applicable to the observational level.

Card type ---- OBS designates observed levels. STD indicates the values at this standard level were interpolated by a modified 3-point LaGrange formula.

Depth (m.) ---- Depth to nearest meter. A postscript T indicates depth was obtained thermometrically; Z indicates uncorrected "wire out" depth. Postscript Q indicates value was marked doubtful by originator; P indicates value was considered doubtful by NODC. Postscripts P and Q retain this meaning throughout the following entries.

T °C.	Temperature to hundredths of a degree Celsius.
S ‰	Salinity in parts-per-thousands.
SIGMA–T	Entered to hundredths.
Specific-volume	Multiply entry by 10^{-7} to obtain specific-volume anomaly in cubic centimeters per gram.
$\Sigma\Delta D$ Dyn. M $\times 10^{3}$	Multiply entry by 10^{-3} to obtain anomaly of dynamic depth in dynamic meters referenced to the sea surface.
Sound velocity	Sound velocity according to Wilson's formula entered to tenths of a meter per second.
O_2 ml/1	Dissolved oxygen in milliliters per liter entered to hundredths.
PO_4-P μg-at/l.	Inorganic phosphate in microgram-atoms per liter entered to hundredths.
Total-P μg-at/l.	Total phosphorous in microgram-atoms per liter entered to hundredths.
NO_2-N μg-at/l.	Nitrite-nitrogen in microgram-atoms per liter entered to hundredths.
NO_3-N μg-at/l.	Nitrate-nitrogen in microgram-atoms per liter entered to tenths.
SiO_4-Si μg-at/l.	Silicate-silicon in microgram-atoms per liter entered to whole units.
pH	Entered to hundredths.

Table I.—Observed and interpolated oceanographic data from stations taken by USCGC GLACIER, 25 September–17 October 1970, prepared from NODC listing No. 31-1706.

Reference: Ctry Code / ID. No.	Ship Code	Latitude ° ' 1/10	Longitude ° ' 1/10	Deep Index	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
311706	GL	69446N	163338W		233	93	09	26	007	1970	CSS	008	0019		24	2	2		X7	6	8	0001

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		24	S22	098			7	05	

Message Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly-×10⁷	Σ Δ D Dyn. M. × 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STO	0000	0344	3100	2468	0032677	0000	14591	701							
007		OBS	0000	0344						701							
007		OBS	0004	0347	31000	2468			14593	708							
007		OBS	0009	0342	30993	2468			14591	691							
		STO	0010	0342	3099	2468	0032725	0032	14592	697							
007		OBS	0013	0344	30992	2468			14593	707							
007		OBS	0016	0347	30992	2468			14595	703							

Reference: Ctry Code / ID. No.	Ship Code	Latitude ° ' 1/10	Longitude ° ' 1/10	Deep Index	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
311706	GL	69446N	163338W		233	93	09	27	091	1970	CSS	008	0019		29	2	2		X7	6	8	0002

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		29	S04	192	+032	+039	7	05	

Message Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly-×10⁷	Σ Δ D Dyn. M. × 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STO	0000	0336	3097	2467	0032804	0000	14587								
091		OBS	0000	0336	30975	2467			14587								
091		OBS	0005	0338	30973	2467			14589								
		STD	0010	0335	3097	2467	0032834	0032	14588								
091		OBS	0010	0335	30970	2467			14588								
091		OBS	0015	0337	30970	2467			14590								
091		OBS	001P	0338	30972	2467			14591								

Reference: Ctry Code / ID. No.	Ship Code	Latitude ° ' 1/10	Longitude ° ' 1/10	Deep Index	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
311706	GL	70095N	166026W		269	06	09	28	011	1970	CSS	009	0044		32	0	2		X7	6	8	0003

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		32	S21	180	+056	+062	7	05	

Message Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly-×10⁷	Σ Δ D Dyn. M. × 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STO	0000	0177	3142	2515	0028274	0000	14523	754							
011		OBS	0000	0177	31419	2515			14523	754	061		004	005	017		
		STO	0010	0178	3142	2515	0028291	0028	14526	757							
011		OBS	0010	0178	31418	2515			14526	757	062		005	005	017		
		STO	0020	0293	3171	2529	0026891	0055	14582	739							
011		OBS	0020	0293	31711	2529			14582	739	066		009	006	018		
		STO	0030	0310	3174	2530	0026795	0082	14591	737							
011		OBS	0030	0310	31742	2530			14591	737	066		004	008	018		
011		OBS	0040	0247	32243	2575			14572	656	146		023	025	041		

Reference Ctry Code / ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
311706	GL	7019 N	16545 W		269	05	09	28	176	1970	CSS	011	0043		00	0	X		X2	6	8		0004

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		33	S03	166	-071	-071	7	05	

Messenger Time or T Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STD	0000	0010	3047	2447	0034694	0000	14435	802							
176		OBS	0000	0010	30467	2447			14435	802	037		011	001	008		
		STD	0010	0180	3120	2497	0029934	0032	14523	755							
176		OBS	0010	0180	31204	2497			14523	755	054		001	001	014		
		STD	0020	0304	3170	2528	0027055	0060	14586	725							
176		OBS	0020	0304	31701	2528			14586	725	068		004	005	017		
		STD	0030	0306	3174	2531	0026777	0087	14589	726							
176		OBS	0030	0306	31740	2531			14589	726	070		007	006	018		
176		OBS	0042	0192	32435	2595			14551	681	152		017	026	043		

Reference Ctry Code / ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
311706	GL	7028 N	16515 W		269	05	09	29	015	1970	CSS	012	0044		35	0	2		X2	6	8		0005

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		35	S20	159	-083	-083	7	05	

Messenger Time or T Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STD	0000	-0099	2983	2399	0039266	0000	14375	835							
015		OBS	0000	-0099	29829	2399			14375	835	043		003	002	008		
		STD	0010	-0068	2999	2412	0038056	0038	14393	831							
015		OBS	0010	-0068	29994	2412			14393	831	036		000	001	007		
		STD	0020	0169	3094	2477	0031847	0073	14517	767							
015		OBS	0020	0169	30943	2477			14517	767	046		000	001	010		
		STD	0030	0295	3195	2548	0025081	0102	14587	715							
015		OBS	0030	0295	31953	2548			14587	715	093		012	012	023		
015		OBS	0042	0223	32316	2583			14563	681	151		023	022	042		

Reference Ctry Code / ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
311706	GL	7018 N	16441 W		269	04	09	29	238	1970	CSS	015	0042		31	2	2		X2	6	8		0006

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		31	S11	146	-066	-062	7	05	

Messenger Time or T Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STD	0000	0120	3095	2481	0031496	0000	14491	738							
238		OBS	0000	0120	30952	2481			14491	738	050		014	000	014		
		STD	0010	0126	3097	2482	0031412	0031	14496	743							
238		OBS	0010	0126	30967	2482			14496	743	051		006	001	014		
		STD	0020	0279	3141	2506	0029094	0061	14571	755							
238		OBS	0020	0279	31406	2506			14571	755	047		004	001	012		
		STD	0030	0326	3160	2518	0028011	0090	14596	732							
238		OBS	0030	0326	31599	2518			14596	732	056		008	[illegible]	013		
238		OBS	0040	0277	32126	2564			14584	578	134		011	[illegible]	044		

Reference (Ctry Code / ID No.)	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indic.	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
311706	GL	7024 N	16409 W		269	04	09	30	174	1970	CSS	018	0040		29	0	2		X2	6	8	0007

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		29	S11	138	+077	+081	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁵	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH
		STD	0000	0175	3111	2490	0030643	0000	14518	747						
174		OBS	0000	0175	31106	2490			14518	747	048		009	001	010	
		STD	0010	0177	3110	2489	0030669	0030	14521	748						
174		OBS	0010	0177	31104	2489			14521	748	045		004	003	010	
		STD	0020	0182	3112	2490	0030577	0061	14525	745						
174		OBS	0020	0182	31120	2490			14525	745	043		000	001	011	
		STD	0030	0332	3144	2505	0029255	0091	14597	714						
174		OBS	0030	0332	31441	25[illegible]			14597	714	054		005	002	014	
174		OBS	0039	0323	32064	2555			14603	636	013		010	019	038	

Reference (Ctry Code / ID No.)	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indic.	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
311706	GL	7022 N	16316 W		269	03	10	01	001	1970	CSS	019	0030		00	0	X		X1	3	7	0008

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		31	S05	134	+090	+094	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁵	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH
		STD	0000	-0077	3009	2420	0037266	0000	14389	795						
001		OBS	0000	-0077	30095	2420			14389	795	029		001	001	006	
001		OBS	0006	-0072	30085	2419			14392	794	032		001	001	006	
		STD	0010	0100	3067	2459	0033563	0035	14480	768						
001		OBS	0014	0223	31720	2535			14550	748	035		002	001	010	
		STD	0020	0299						729						
001		OBS	0022	0323						725	041		002	001	007	
001		OBS	0028	0390	3140P	2496P				6860	067		004	006	019	

Reference (Ctry Code / ID No.)	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indic.	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
311706	GL	7034 N	16316 W		269	03	10	02	010	1970	CSS	021	0038		30	0	2		X2	3	8	0009

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		30	S04	195	+069	+071	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁵	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH
		STD	0000	-0102	2998	2412	0038075	0000	14376	790						
010		OBS	0000	-0102	29983	2412			14376	790	043		007	004	007	
010		OBS	0009	-0002	30265	2432			14428	774	013		006	002	007	
		STD	0010	0045	3042	2442	0035206	0036	14452	766						
010		OBS	0018	0305	31268	2493			14581	721	011		012	001	009	
		STD	0020	0314	3128	2494	0030294	0069	14585	720						
010		OBS	0027	0343	31419	2502			14600	718	020		013	001	011	
		STD	0030	0355	3152	2508	0028884	0099	14607	697						
010		OBS	0036	0377	31776	2527			14621	627	038		033	015	039	

Reference Ctry Code	ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift NODC	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	7023 N	16224 W		269	02	10	02	205	1970	CSS	023	0024		00	0	X		X7	7	8		0010

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis Code	No. Obs. Depths	Special Observations
		27	S03	241	-077	-077	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. x 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STD	0000	-0104	3002	2415	0037748	0000	14375	812							
205		OBS	0000	-0104	30025	2415			14375	812	033		011	00[illegible]	0[illegible]8		
205		OBS	0005	-0056	30098	2420			14400	803	031		002	001	009		
		STD	0010	0024	3031	2434	0035932	0036	14441	768							
205		OBS	0010	0024	30311	2434			14441	768	037		002	001	011		
205		OBS	0015	0130	30524	2446			14493	748	047		003	003	015		
		STD	0020	0329	3124	2489	0030721	0070	14591	671							
205		OBS	0022	0434	31672	2513			14642	625	097		008	011	032		

Reference Ctry Code	ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift NODC	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	7009 N	16257 W		269	02	10	03	029	1970	CSS	024	0018		00	0	X		X1	6	3		0011

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis Code	No. Obs. Depths	Special Observations
		33	S02	228	-076	-078	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. x 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STD	0000	0030	3039	2440	0035384	0000	14443	768							
029		OBS	0000	0030	30387	2440			14443	768	045		004	002	011		
029		OBS	0003	0040	30417	2442			14448	770	044		002	001	012		
029		OBS	0008	0069	30481	2446			14463	755	044		002	001	012		
		STD	0010	0217	3077	2460	0033457	0034	14534	729							
029		OBS	0012	0320	31000	2470			14582	706	058		002	004	017		
029		OBS	0017	0380	31302	2489			14613	663	070		003	005	022		

Reference Ctry Code	ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift NODC	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	7011 N	16252 W		269	02	10	03	195	1970	CSS	026	0019		00	0	X		X4	X	9		0012

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis Code	No. Obs. Depths	Special Observations
		00	S00	216	-094	-094	1	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. x 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STD	0000	-0032	3025	2431	0036211	0000	14412	789							
195		OBS	0000	-0032	30249	2431			14412	789	034		004	008	008		
195		OBS	0004	-0031	30249	2431			14413	793	034		000	001	008		
195		OBS	0009	0028	30301	2433			14442	782	037		000	006	009		
		STD	0010	0115	3036	2434	0035962	0036	14483	761							
195		OBS	0014	0339						697	056		003	004	016		
195		OBS	0017	0376	31275	2487			14611	667	062		002	009	020		

REFERENCE CTRY CODE	REFERENCE I.D. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	DEPTH INDICATOR	MARSDEN SQUARE 10°	MARSDEN SQUARE 1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	ORIGINATOR'S STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF S'MPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
31	1706	GL	6959 N	16317 W		233	93	10	04	178	1970	CSS	028	0020		00	0	X		X4	X	9		0013

WATER COLOR CODE	WATER TRANS. (m)	WIND DIR.	WIND SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	AIR TEMP. °C WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		12	S04	223	-062	-062	1	05	

MESSENGR TIME HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY×10⁷	ΣΔD DYN. M. X 10³	SOUND VELOCITY	O₂ ml/l	PO₄-P µg-at/l	TOTAL-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STD	0000	0131	3088	2474	0032105	0000	14495	761						
178		OBS	0000	0131	30880	2474			14495	761	044		009	000	009	
178		OBS	0005	0144	30884	2474			14502	757	044		002	000	009	
		STD	0010	0159	3092	2476	0031985	0032	14510	753						
178		OBS	0010		30917					753	046		004	001	009	
178		OBS	0015	0194	30959	2477			14527	748	048		003	000	010	
178		OBS	0018	0225	31038	2481			14542	712	051		004	002	018	

REFERENCE CTRY CODE	REFERENCE I.D. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	DEPTH INDICATOR	MARSDEN SQUARE 10°	MARSDEN SQUARE 1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	ORIGINATOR'S STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF S'MPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
31	1706	GL	7001 N	16359 W		269	03	10	05	006	1970	CSS	029	0030		00	0	X		X7	6	8		0014

WATER COLOR CODE	WATER TRANS. (m)	WIND DIR.	WIND SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	AIR TEMP. °C WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		00	S00	222	-001	-013	6	05	

MESSENGR TIME HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY×10⁷	ΣΔD DYN. M. X 10³	SOUND VELOCITY	O₂ ml/l	PO₄-P µg-at/l	TOTAL-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STD	0000	0237	3110	2485	0031088	0000	14546	742						
006		OBS	0000	0237	31102	2485			14546	742	052		001	001	016	
006		OBS	0007	0243	31110	2485			14550	742	051		002	001	016	
		STD	0010	0241	3111	2485	0031070	0031	14549	742						
006		OBS	0014	0238	31106	2485			14548	743	05C		001	001	015	
		STD	0020	0265	3117	2488	0030781	0062	14562	734						
006		OBS	0021	0275	31188	2489			14567	728	053		001	002	016	
006		OBS	0028	0387	31390	2496			14619	645	096		003	008	036	

REFERENCE CTRY CODE	REFERENCE I.D. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	DEPTH INDICATOR	MARSDEN SQUARE 10°	MARSDEN SQUARE 1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	ORIGINATOR'S STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF S'MPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
31	1706	GL	6945 N	16334 W		233	93	10	05	181	1970	CSS	031	0020		24	2	2		X4	6	5		0015

WATER COLOR CODE	WATER TRANS. (m)	WIND DIR.	WIND SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	AIR TEMP. °C WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		06	S04	255	-039	-044	6	05	

MESSENGR TIME HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY×10⁷	ΣΔD DYN. M. X 10³	SOUND VELOCITY	O₂ ml/l	PO₄-P µg-at/l	TOTAL-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STD	0000	0086	3081	2471	0032423	0000	14474	764						
181		OBS	0000	0086	30808	2471			14474	764	079		004	004	038	
181		OBS	0005	0089	30810	2471			14476	765	082		003	004	038	
		STD	0010	0087	3081	2471	0032409	0032	14476	764						
181		OBS	0010	0087	30809	2471			14476	764	083		003	004	038	
181		OBS	0015	0112	30887	2476			14489	755	089		004	004	041	
181		OBS	0019	0115												

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
31	1706	GL	6947 N	16430 W		233	94	10	06	142	1970	CSS	033	0030		05	2	2		X2	6	8	0016

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		05	S20	121	-049	-051	7	05	

Messenger Time or HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. × 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STO	0000	0308	3114	2482	0031351	0000	14577	718						
142		OBS	0000	0308	31137	2482			14577	718	060		004	004	027	
142		OBS	0007	0312	31134	2482			14580	718	058		002	004	028	
		STO	0010	0309	3114	2482	0031362	0031	14579	718						
142		OBS	0014	0307	31138	2483			14579	718	060		005	005	024	
		STO	0020	0309	3114	2482	0031355	0062	14581	720						
142		OBS	0020	0309	31138	2482			14581	720	058		001	004	024	
142		OBS	0027		31146					773	063		004	004	024	

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
31	1706	GL	6956 N	16537 W		233	95	10	06	183	1970	CSS	034	0040		05	4	2		X2	6	8	0017

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		05	S26	106	-060	-061	7	06	

Messenger Time or HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. × 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STO	0000	0321	3133	2496	0030007	0000	14585	731						
183		OBS	0000	0321	31328	2496			14585	731	076		001	004	023	
183		OBS	0007	0328	31454	2506			14591	717	076		002	003	023	
		STO	0010	0325	3146	2506	0029075	0029	14590	717						
183		OBS	0015	0322	31458	2507			14590	716	078		001	003	024	
		STO	0020	0324	3146	2506	0029069	0058	14592	716						
183		OBS	0026	0326	31454	2506			14593	716	079		001	003	024	
		STD	0030	0327	3145	2506	0029127	0087	14595	716						
183		OBS	0033	0329	31480	2508			14596	714	066		001	003	024	
183		OBS	0042	0337												

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt	NODC Station Number
31	1706	GL	6959 N	16630 W		233	96	10	06	230	1970	CSS	035	0045		35	3	2		X3	6	8	0018

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		04	S26	108	-058	-061	7	06	

Messenger Time or HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. × 10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STO	0000	0279	3154	2517	0028038	0000	14570	729						
230		OBS	0000	0279	31545	2517			14570	729	073		001	003	019	
230		OBS	0008	0280	31542	2517			14572	730	072		001	003	018	
		STO	0010	0278	3155	2517	0028022	0028	14571	730						
230		OBS	0015	0275	31550	2518			14571	729	075		001	003	019	
		STO	0020	0276	3155	2518	0027987	0056	14572	729						
230		OBS	0023	0278	31548	2518			14573	729	072		002	003	019	
		STO	0030	0287	3155	2517	0028099	0084	14579	729						
230		OBS	0031	0288	31701	2529			14581	724	076		003	004	018	
230		OBS	0041	0284												

REFERENCE CTRY CODE / ID. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	DEPTH INDICATOR	MARSDEN SQUARE 10°	1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF S'MPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
311706	GL	7008 N	16711 W		269	07	10	07	032	1970	CSS	036	0048		04	4	2		X7	6	7		0019

WATER COLOR CODE	TRANS. (m)	WIND DIR.	SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		04	S27	111	+092	+093	6	06	

MESSENGER TIME OR T HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY×10⁷	Σ Δ D DYN. M. x 10³	SOUND VELOCITY	O_2 ml/l	PO_4-P µg-at/l	TOTAL-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH
		STD	0000	0217	3165	2530	0026768	0000	14544	746						
032		OBS	0000	0217	31652	2530			14544	746	068					
032		OBS	0009	0217	31649	2530			14546	744	072					
		STD	0010	0216	3165	2530	0026786	0026	14545	744						
032		OBS	0018	0210	31647	2531			14544	744	071					
		STD	0020	0210	3165	2531	0026769	0053	14545	744						
032		OBS	0026	0211	31646	2530			14546	744	072					
		STD	0030	0211	3165	2530	0026787	0080	14547	744						
032		OBS	0035	0212	31667	2532			14548	745	075					
032		OBS	0044	0158												

REFERENCE CTRY CODE / ID. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	DEPTH INDICATOR	MARSDEN SQUARE 10°	1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF S'MPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
311706	GL	6949 N	16629 W		233	96	10	07	143	1970	CSS	038	0044		04	4	2		X7	6	8		0020

WATER COLOR CODE	TRANS. (m)	WIND DIR.	SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		04	S33	074	+056	+056	6	06	

MESSENGER TIME OR T HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY×10⁷	Σ Δ D DYN. M. x 10³	SOUND VELOCITY	O_2 ml/l	PO_4-P µg-at/l	TOTAL-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH
		STD	0000	0337	3148	2507	0029009	0000	14594	720						
143		OBS	0000	0337	31478	2507			14594	720	070		002	002	020	
143		OBS	0008	0340	31462	2505			14597	724	071		002	003	020	
		STD	0010	0338	3146	2506	0029150	0029	14596	724						
143		OBS	0015	0335	31465	2506			14596	724	071		002	002	020	
		STD	0020	0338	3146	2506	0029125	0058	14598	719						
143		OBS	0024	0340	31463	2506			14599	718	072		02	002	021	
		STD	0030	0341	3146	2505	0029201	0087	14601	722						
143		OBS	0032	0341	31455	2505			14601	725	072		002	002	020	
143		OBS	0039	0334	31888	2540			14605	690Q	092		008	008	026	

REFERENCE CTRY CODE / ID. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	DEPTH INDICATOR	MARSDEN SQUARE 10°	1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	STATION NUMBER	DEPTH TO BOTTOM	MAX. DEPTH OF S'MPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
311706	GL	6951 N	16647 W		233	96	10	07	180	1970	CSS	039	0051		05	4	2		X7	7	8		0021

WATER COLOR CODE	TRANS. (m)	WIND DIR.	SPEED OR FORCE	BAROMETER (mbs)	AIR TEMP. °C DRY BULB	WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		05	S30	071	+ 58	+058	6	06	

MESSENGER TIME OR T HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY×10⁷	Σ Δ D DYN. M. x 10³	SOUND VELOCITY	O_2 ml/l	PO_4-P µg-at/l	TOTAL-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH
		STD	0000	0276	3161	2522	0027530	0000	14570	735						
180		OBS	0000	0276	31608	2522			14570	735	071		003	002	018	
180		OBS	0008	0278	31611	2523			14572	736	071		003	002	018	
		STD	0010	0277	3161	2523	0027523	0027	14572	736						
180		OBS	0018	0275	31612	2523			14572	736	072		003	002	018	
		STD	0020	0276	3161	2523	0027507	0056	14573	736						
180		OBS	0027	0277	31616	2523			14575	736	071		003	004	018	
		STD	0030	0274	3162	2523	0027454	0084	14574	736						
180		OBS	0036	0268	31704	2531			14573	724	080		007	006	021	
180		OBS	0043	0210												

Reference Ctry Code / IO No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Cruise No.	Station Number	Depth to Bottom	Max Depth of S'mpl's	Wave Dir	Hgt	Per	Sea	Weather Code	Cloud Type	Cloud Amt	NODC Station Number
311706	GL	7018 N	16657 W	269	06	10	07	232	1970	CSS	040	0047		00	0	X		X1	5	7	0022

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S27	083	-097	-099	7	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O2 ml/l	PO4-P	Total-P	NO2-N	NO3-N	SiO4-Si	pH
		STD	0000	-0001	3093	2485	0031115	0000	14436	758						
232		OBS	0000	-0001	30928	2485			14436	758	063		001	002	014	
232		OBS	0009	0006	30926	2484			14441	761	060		002	001	014	
		STD	0010	0006	3093	2485	0031145	0031	14441	761						
232		OBS	0018	0007	30942	2486			14443	760	060		002	002	014	
		STD	0020	0016	3096	2487	0030922	0062	14447	759						
232		OBS	0027	0046	31028	2491			14463	754	064		003	002	014	
		STD	0030	0174	3146	2518	0027954	0091	14528	716						
232		OBS	0036	0293	32077	2558			14589	666	118		022	01[illegible]	032	
232		OBS	0043	0199	32389	2591			14554	650	157		028	024	049	

Reference Ctry Code / IO No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Cruise No.	Station Number	Depth to Bottom	Max Depth of S'mpl's	Wave Dir	Hgt	Per	Sea	Weather Code	Cloud Type	Cloud Amt	NODC Station Number
311706	GL	7000 N	16741 W	269	07	10	08	138	1970	CSS	042	0052		03	4	2		X2	6	8	0023

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S22	085	-069	-071	7	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O2 ml/l	PO4-P	Total-P	NO2-N	NO3-N	SiO4-Si	pH
		STD	0000	0247	3163	2526	0027158	0000	14557	740						
138		OBS	0000	0247	31629	2526			14557	740	073		003	004	018	
138		OBS	0008	0249	31629	2526			14559	739	075		003	004	019	
		STD	0010	0247	3163	2526	0027159	0027	14559	739						
138		OBS	0018	0242	31629	2527			14558	740	078		003	005	018	
		STD	0020	0243	3163	2527	0027133	0054	14559	740						
138		OBS	0027	0244	31629	2527			14560	739	077		003	005	018	
		STD	0030	0243	3163	2527	0027134	0081	14561	739						
138		OBS	0037	0242	31628	2527			14561	738	079		003	004	019	
138		OBS	0045	0150	32468	2600			14533	691	150		018	025	038	

Reference Ctry Code / IO No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Cruise No.	Station Number	Depth to Bottom	Max Depth of S'mpl's	Wave Dir	Hgt	Per	Sea	Weather Code	Cloud Type	Cloud Amt	NODC Station Number
311706	GL	7003 N	16826 W	269	08	10	08	178	1970	CSS	043	0046		03	3	2		X1	6	7	0024

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S20	095	-089	-089	7	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O2 ml/l	PO4-P	Total-P	NO2-N	NO3-N	SiO4-Si	pH
		STD	0000	0163	3175	2542	0025634	0000	14522	749						
178		OBS	0000	0163	31755	2542			14522	749	071		008	005	018	
178		OBS	0008	0165	31755	2542			14524	749	074		009	004	018	
		STD	0010	0164	3176	2542	0025624	0025	14524	750						
178		OBS	0018	0161	31758	2543			14524	752	073		008	005	018	
		STD	0020	0161	3176	2543	0025605	0051	14524	752						
178		OBS	0026	0162	31754	2542			14526	753	078		008	004	018	
		STD	0030	0167	3204	2565	0023503	0075	14533	735						
178		OBS	0035	0174	32361	2590			14541	724	121		040	016	026	
178		OBS	0041	0093	32700	2622			14510	726	142		025	026	034	

Ctry code	ID No.	Ship code	Latitude ° 1/10	Longitude ° 1/10	Depth index	Marsden square 10°	1°	MO	DAT	HR 1/10	Year	Cruise No.	Station number	Depth to bottom	Max. depth of smpls	Wave dir.	Hgt	Per	Sea	Weather code	Cloud type	Cloud amt		NODC station number
31	1706	GL	7011 N	16856 W		269	08	10	08	228	1970	CSS	044	0036		00	0	X		X1	6	1		0025

Water color code	Trans. (m)	Wind dir.	Speed or force	Barometer (mbs)	Air temp. °C dry bulb	Wet bulb	Vis. code	No. obs. depths	Special observations
		02	S08	105	+104	+106	7	06	

Messenger time HR 1/10	Cast no.	Card type	Depth (m)	T °C	S ‰	Sigma-T	Specific volume anomaly ×10⁵	ΣΔD dyn. m. ×10³	Sound velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STO	0000	0095	3160	2534	0026387	0000	14489	765						
228		OBS	0000	0095	31604	2534			14489	765	073		009	005	016	
228		OBS	0006	0095	31606	2535			14490	764	075		007	005	016	
		STO	0010	0094	3160	2534	0026402	0026	14490	765						
228		OBS	0013	0093	31599	2534			14490	765	071		010	006	016	
		STD	0020	0109	3169	2540	0025820	0052	14500	763						
228		OBS	0020	0109	31688	2540			14500	763	076		011	006	017	
228		OBS	0027	0113	31767	2547			14504	758	082		012	009	018	
		STO	0030	0111	3188	2556	0024341	0077	14505	754						
228		OBS	0033	0107	32052	2570			14506	749	094		008	011	022	

Ctry code	ID No.	Ship code	Latitude ° 1/10	Longitude ° 1/10	Depth index	Marsden square 10°	1°	MO	DAT	HR 1/10	Year	Cruise No.	Station number	Depth to bottom	Max. depth of smpls	Wave dir.	Hgt	Per	Sea	Weather code	Cloud type	Cloud amt		NODC station number
31	1706	GL	7001 N	16834 W		269	08	10	09	143	1970	CSS	048	0041		09	0	2		X2	3	8		0026

Water color code	Trans. (m)	Wind dir.	Speed or force	Barometer (mbs)	Air temp. °C dry bulb	Wet bulb	Vis. code	No. obs. depths	Special observations
		09	S03	107	+073	+084	7	06	

Messenger time HR 1/10	Cast no.	Card type	Depth (m)	T °C	S ‰	Sigma-T	Specific volume anomaly ×10⁵	ΣΔD dyn. m. ×10³	Sound velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STC	0000	0148	3174	2542	0025652	0000	14515	752						
143		OBS	0000	0148	31740	2542			14515	752	065		010	006	018	
143		OBS	0008	0147	31735	2542			14516	753	068		010	005	018	
		STO	0010	0146	3174	2542	0025678	0025	14515	752						
143		OBS	0016	0144	31737	2542			14516	749	069		010	005	018	
		STO	0020	0146	3174	2542	0025659	0051	14517	749						
143		OBS	0024	0147	31738	2542			14518	749	065		010	005	018	
		STO	0030	0146	3174	2543	0025622	0077	14519	786						
143		OBS	0032	0146	31744	2543			14519	798	072		011	005	018	
143		OBS	0038	0094	32662	2619			14510	697	136		032	026	033	

Ctry code	ID No.	Ship code	Latitude ° 1/10	Longitude ° 1/10	Depth index	Marsden square 10°	1°	MO	DAT	HR 1/10	Year	Cruise No.	Station number	Depth to bottom	Max. depth of smpls	Wave dir.	Hgt	Per	Sea	Weather code	Cloud type	Cloud amt		NODC station number
31	1706	GL	6948 N	16805 W		233	98	10	09	181	1970	CSS	049	0047		07	0	2		X2	3	8		0027

Water color code	Trans. (m)	Wind dir.	Speed or force	Barometer (mbs)	Air temp. °C dry bulb	Wet bulb	Vis. code	No. obs. depths	Special observations
		07	S04	099	+072	+077	7	06	

Messenger time HR 1/10	Cast no.	Card type	Depth (m)	T °C	S ‰	Sigma-T	Specific volume anomaly ×10⁵	ΣΔD dyn. m. ×10³	Sound velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STO	0000	0303	3145	2508	0028918	0000	14579	724						
181		OBS	0000	0303	31453	2508			14579	724	082		005	003	020	
181		OBS	0009	0303	31453	2508			14581	724	076		005	003	019	
		STO	0010	0303	3145	2508	0028921	0028	14581	724						
181		OBS	0018	0301	31451	2508			14581	725	078		005	003	020	
		STO	0020	0301	3145	2508	0028932	0057	14582	728						
181		OBS	0027	0304	31449	2508			14584	731	076		005	003	020	
		STO	0030	0306	3148	2510	0028763	0086	14586	727						
181		OBS	0036	0309	31533	2514			14589	720	083		006	004	020	
181		OBS	0043	0198	32308	2584			14552	657	154		022	025	042	

Reference: Ctry Code	Reference: ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Deep/Shallow	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6938 N	16744 W		233	97	10	10	010	1970	CSS	050	0046		[illegible]	0	X		X7	6	8		0028

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		10	S08	077	+057	+066	7	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STD	0000	0335	3132	2495	0030171	0000	14591	713							
010		OBS	0000	0335	31322	2495			14591	713	066		002	004	023		
010		OBS	0009	0337	31324	2495			14594	720	069		003	004	023		
		STD	0010	0336	3132	2495	0030165	0030	14593	719							
010		OBS	0018	0332	31325	2495			14593	718	067		002	004	023		
		STD	0020	0332	3133	2495	0030122	0060	14594	723							
010		OBS	0027	0334	31329	2495			14595	727	065		003	004	023		
		STD	0030	0345	3135	2496	0030027	0090	14601	724							
010		OBS	0036	0348	31400	2500			14604	701	068		003	007	027		
010		OBS	0043	0321	31752	2530			14598	643	097		014	018	040		

Reference: Ctry Code	Reference: ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Deep/Shallow	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6924 N	16715 W		233	97	10	10	155	1970	CSS	054	0047		03	2	2		X7	3	8		0029

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S15	099	+058	+062	6	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STD	0000	0276	3146	2511	0028619	0000	14568	712							
155		OBS	0000	0276	31465	2511			14568	712	090		011	014	023		
155		OBS	0009	0279	31464	2511			14570	713	093		008	014	024		
		STD	0010	0278	3146	2511	0028648	0028	14570	713							
155		OBS	0018	0275	31460	2511			14570	711	092		009	015	024		
		STD	0020	0276	3146	2511	0028650	0057	14571	711							
155		OBS	0027	0278						711	092		008	01[illegible]	024		
		STD	0030	0278	3147	2511	0028634	0085	14574	712							
155		OBS	0036	0279	31469	2511			14575	713	093		009	016	024		
155		OBS	0043	0343	31747	2528			14608	624	130		025	025	042		

Reference: Ctry Code	Reference: ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Deep/Shallow	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6913 N	16652 W		233	96	10	10	233	1970	CSS	055	0040		05	1	2		X7	7	8		0030

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		33	S10	137	+072	+078	6	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STD	0000	0244	3143	2511	0028628	0000	14553	740							
233		OBS	0000	0244	31432	2511			14553	740	094		002	011	021		
233		OBS	0007	0246	31426	2510			14555	734	089		001	012	021		
		STD	0010	0244	3143	2511	0028647	0028	14555	734							
233		OBS	0014	0242	31434	2511			14555	734	090		001	012	021		
		STD	0020	0241	3143	2511	0028593	0057	14555	736							
233		OBS	0021	0240	31434	2511			14555	736	091		006	012	021		
233		OBS	0028	0227	31436	2513			14550	738	087		005	011	022		
		STD	0030	0224	3144	2513	0028448	0085	14550	739							
233		OBS	0036	0220	31447	2514			14549	740	090		006	010	022		

Reference Ctry Code	ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Quadrant	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) MO	DAY	HR 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6904 N	16640 W		233	96	10	11	150	1970	CSS	059	0041		04	1	2		X7	7	7		0031

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		04	S03	126	-083	-088	7	06	

Messenger Time HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O_2 ml/l	PO_4-P	Total-P	NO_2-N	NO_3-N	SiO_4-Si	pH
		STO	0000	0208	3137	2508	0028873	0000	14536	739						
150		OBS	0000	0208	31367	2508			14536	739	094		006	013	022	
150		OBS	0008	0209	31358	2508			14538	745	091		007	012	022	
		STO	0010	0207	3136	2508	0028936	0028	14538	742						
150		OBS	0015	0205	31360	2508			14538	739	090		006	012	022	
		STO	0020	0206	3136	2508	0028882	0057	14539	741						
150		OBS	0023	0207	31365	2508			14540	742	095		006	012	022	
		STO	0030	0210	3136	2508	0028909	0086	14542	743						
150		OBS	0031	0211	31364	2508			14543	743	094		006	012	022	
150		OBS	0035	0208	31380	2509			14542	740	092		006	012	022	

Reference Ctry Code	ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Quadrant	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) MO	DAY	HR 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6857 N	16625 W		233	86	10	11	216	1970	CSS	060	0035		05	3	2		X1	6	7		0032

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		05	S22	121	-072	-077	7	05	

Messenger Time HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O_2 ml/l	PO_4-P	Total-P	NO_2-N	NO_3-N	SiO_4-Si	pH
		STO	0000	0161	3121	2499	0029780	0000	14513	746						
216		OBS	0000	0161	31209	2499			14513	746	090		007	010	024	
216		OBS	0005	0165	31232	2500			14516	747	095		006	011	024	
		STO	0010	0167	3126	2503	0029416	0029	14519	745						
216		OBS	0013	0169	31282	2504			14520	744	096		007	012	023	
		STD	0020	0194	3135	2508	0028935	0058	14533	742						
216		OBS	0021	0196	31353	2508			14534	742	097		007	013	023	
215		OBS	0028	0203	31388	2510			14539	737	098		006	015	022	

Reference Ctry Code	ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Quadrant	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) MO	DAY	HR 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6906 N	16602 W		233	96	10	12	185	1970	CSS	062	0026		06	4	2		X7	7	8		0033

Water Color Code	Trans. (m)	Wind Dir.	Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		06	S25	210	-122	-122	5	05	

Messenger Time HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O_2 ml/l	PO_4-P	Total-P	NO_2-N	NO_3-N	SiO_4-Si	pH
		STO	0000	0077	3077	2468	0032677	0000	14469	773						
185		OBS	0000	0077	30763	2468			14469	773	095		003	008	030	
185		OBS	0002	0080	30765	2468			14471	773	089		004	005	030	
185		OBS	0008	0076	30762	2468			14470	773	087		001	008	030	
		STO	0010	0076	3076	2468	0032718	0032	14471	773						
185		OBS	0013	0078	30761	2468			14472	772	092		000	006	030	
185		OBS	0017	0084	30750	24670				780	077		000	008	029	

Reference Ctry Code	Reference ID. No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Deg. Sq. Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6914 N	16556 W		233	95	10	12	220	1970	CSS	063	0035		04	3	2		X7	7	8		0034

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S33	207	-119	-120	5	05	

Message Time HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly×10^7	ΣΔD Dyn. M. ×10^3	Sound Velocity	O2 ml/l	PO4-P µg-at/l	Total-P µg-at/l	NO2-N µg-at/l	NO3-N µg-at/l	SiO4-Si µg-at/l	pH	SCC
		STO	0000	0098	3085	2474	0032168	0000	14480	779							
220		OBS	0000	0098	30849	2474			14480	779	065		000	C07	035		
220		OBS	0006	0103	30845	2473			14483	762	061		000	005	035		
		STO	0010	0101	3084	2473	0032210	0032	14483	765							
220		OBS	0014	0100	30845	2473			14483	766	063		001	007	035		
		STO	0020	0102	3084	2473	0032216	0064	14485	762							
220		OBS	0022	0103	30845	2473			14486	762	059		000	004	035		
220		OBS	0028	0105	30845	2473			14488	764	060		000	007	035		

Reference Ctry Code	Reference ID. No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Deg. Sq. Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6925 N	16629 W		233	96	10	13	017	1970	CSS	064	0038		06	4	2		X7	7	8		0035

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S31	183	-101	-105	5	06	

Message Time HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly×10^7	ΣΔD Dyn. M. ×10^3	Sound Velocity	O2 ml/l	PO4-P µg-at/l	Total-P µg-at/l	NO2-N µg-at/l	NO3-N µg-at/l	SiO4-Si µg-at/l	pH	SCC
		STO	0000	0241	3120	2492	0030398	0000	14549	730							
017		OBS	0000	0241	31196	2492			14549	730	070		002	009	027		
017		OBS	0007	0242	31189	2492			14550	731	065		000	007	027		
		STO	0010	0240	3119	2492	0030453	0030	14550	731							
017		OBS	0014	0238	31185	2492			14550	732	073		001	008	028		
		STO	0020	0240	3118	2491	0030544	0060	14551	735							
017		OBS	0021	0240	31176	2491			14551	735	071		001	008	027		
017		OBS	0028	0240	31180	2491			14553	732	071		002	010	027		
		STO	0030	0239	3118	2491	0030499	0091	14553	732							
017		OBS	0035	0237	31186	2492			14553	732	073		002	008	027		

Reference Ctry Code	Reference ID. No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Deg. Sq. Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6938 N	16648 W		233	96	10	13	150	1970	CSS	068	0045		03	3	2		X7	7	8		C036

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S20	198	-117	-119	6	06	

Message Time HR 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly×10^7	ΣΔD Dyn. M. ×10^3	Sound Velocity	O2 ml/l	PO4-P µg-at/l	Total-P µg-at/l	NO2-N µg-at/l	NO3-N µg-at/l	SiO4-Si µg-at/l	pH	SCC
		STO	0000	0252	3119	2491	0030552	0000	14553	739							
150		OBS	0000	0252	31187	2491			14553	739	088		009	003	024		
150		OBS	0009	0252	31195	2491			14555	742	090		002	003	024		
		STO	0010	0251	3120	2491	0030480	0030	14555	741							
150		OBS	0018	0249	31196	2492			14555	738	088		001	003	024		
		STO	0020	0250	3120	2492	0030463	0061	14556	741							
150		OBS	0027	0252	31197	2492			14558	746	090		001	001	024		
		STO	0030	0252	3120	2492	0030446	0091	14559	745							
150		OBS	0036	0252	31204	2492			14560	743	090		001	003	024		
150		OBS	0042	0249	31203	2492			14559	742	091		001	004	024		

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Cloud Codes Amt		NODC Station Number
31	1706	GL	6950 N	16723 W		233	97	10	13	202	1970	CSS	069	0046		03	1	2		X4	7	7		0037

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		03	S25	220	-127	-128	3	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STO	0000	0210	3132	2505	0029208	0000	14537	736							
202		OBS	0000	0210	31325	2505			14537	736	092		002	003	026		
202		OBS	0009	0211	31323	2505			14539	737	090		001	003	026		
		STO	0010	0211	3132	2505	0029245	0029	14539	737							
202		OBS	0019	0213	31314	2504			14541	739	091		002	003	027		
		STO	0020	0214	3131	2504	0029309	0058	14542	739							
202		OBS	0028	0218	31320	2504			14545	736	091		002	003	027		
		STO	0030	0222	3133	2505	0029228	0087	14547	735							
202		OBS	0037	0239	31433	2511			14557	732	098		004	005	029		
202		OBS	0044	0263	31620	2524			14571	683	107		006	008	033		

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Cloud Codes Amt		NODC Station Number
31	1706	GL	6919 N	16511 W		233	95	10	14	198	1970	CSS	072	0029		05	2	2		X7	7	8		0038

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		05	S15	189	-121	-123	6	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STO	0000	-0071	3094	2488	0030779	0000	14404	795							
198		OBS	0000	-0071	30941	2488			14404	795	067		001	003	018		
198		OBS	0004	-0069	30940	2488			14405	800	064		000	003	018		
		STO	0010	-0075	3094	2488	0030780	0030	14403	800							
198		OBS	0011	-0075	30939	2488			14403	800	066		003	003	018		
198		OBS	0017	-0072	30945	2489			14406	800	064		001	003	018		
		STO	0020	-0072	3094	2489	0030744	0061	14406	800							
198		OBS	0024	-0072	30943	2489			14407	799	063		001	003	018		

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Drift Indctr	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Obs. Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Cloud Codes Amt		NODC Station Number
31	1706	GL	6933 N	16437 W		233	94	10	15	011	1970	CSS	073	0026		02	2	2		X7	7	8		0039

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		02	S10	178	-128	-128	5	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH	SCC
		STO	0000	-0028	3176	2553	0024627	0000	14435	739							
011		OBS	0000	-0028	31762	2553			14435	739	125		026	015	035		
011		OBS	0006	-0025	31765	2553			14437	742	106		024	016	034		
		STO	0010	-0024						740							
011		OBS	0012	-0023						739	131		028	015	031		
011		OBS	0018	-0016						737	129		023	016	035		
		STO	0020	-0016													
011		OBS	0023	-0016							127		024	017	035		

Reference Ctry Code	Io. No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6936 N	16510 W	233	95	10	15	139	1970	CSS	077	0032		07	1	2		X7	7	8		0040

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		07	S20	180	-:11	-111	6	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STD	0000	-0103						743						
139		OBS	0000	-0103						743	100		015	011	030	
139		OBS	0006	-0101						745	101		014	012	030	
		STD	0010	-0107						745						
139		OBS	0012	-0108	31100	2502			14390	745	106		017	012	030	
139		OBS	0018	-0103	31103	2502			14394	7500	103		016	012	030	
		STD	0020	-0048	3120	2508	0028855		14421	725						
139		OBS	0024	0031	31343	2517			14460	713	117		017	014	034	
139		OBS	0029	0070	31454	2524			14481	697	129		023	014	036	

Reference Ctry Code	Io. No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6927 N	16538 W	233	95	10	15	194	1970	CSS	078	0033		07	0	2		X7	7	8		0041

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		07	S16	180	-117	-117	5	06	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STD	0000	-0038	3097	2490	0030661	0000	14419	737						
194		OBS	0000	-0038	30970	2490			14419	737	099		010	010	028	
194		OBS	0006	-0036	30970	2490			14421	739	101		012	009	028	
		STD	0010	-0043	3098	2490	0030599	0030	14419	738						
194		OBS	0012	-0045	30977	2490			14418	737	103		013	010	028	
194		OBS	0018	-0047	30978	2491			14418	744	105		012	010	028	
		STD	0020	-0048	3099	2491	0030482	0061	14418	742						
194		OBS	0024	-0049	30999	2492			14419	739	103		012	011	028	
		STD	0030		3099					739						
194		OBS	0030		30993					739	103		012	011	028	

Reference Ctry Code	Io. No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Marsden Square 10°	1°	Station Time (GMT) Mo	Day	Hr 1/10	Year	Originator's Cruise No.	Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6920 N	16436 W	233	94	10	16	146	1970	CSS	084	0024		04	0	2		X7	4	8		0042

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Wet Bulb	Vis. Code	No. Obs. Depths	Special Observations
		04	S16	175	-156	-156	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly ×10⁷	ΣΔD Dyn. M. ×10³	Sound Velocity	O₂ ml/l	PO₄-P µg-at/l	Total-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SiO₄-Si µg-at/l	pH
		STD	0000	-0153	3145	2532	0026641	0000	14372	785						
146		OBS	0000	-0153	31454	2532			14372	785	116		021	013	028	
146		OBS	0005	-0151	31400	25270				790	119		020	013	028	
		STD	0010	-0158	3145	2531	0026676	0026	14371	788						
146		OBS	0010	-0158	31447	2531			14371	788	116		021	014	029	
146		OBS	0015	-0154	31486	2534			14375	789	117		021	014	029	
		STD	0020	-0155						789						
146		OBS	0022	-0155	31440	25310				789	117		019	014	029	

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Date Index	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6913 N	16445 W		233	94	10	16	180	1970	CSS	085	0023		00	0	X		X2	7	8		0043

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis Code	No. Obs. Depths	Special Observations
		04	S12	180	-166	-166	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STO	0000	-0167	3134	2523	0027502	0000	14364	791							
180		OBS	0000	-0167	31339	2523			14364	791	104		014	009	027		
180		OBS	0004	-0164	31336	2522			14366	792	107		016	012	028		
180		OBS	0009	-0168	31333	2522			14365	792	105		016	012	028		
		STO	0010	-0167	3133	2522	0027546	0027	14365	792							
180		OBS	0014	-0165	31331	2522			14367	792	107		018	012	028		
		STO	0020	-0169	3137	2525	0027255	0054	14367	799							
180		OBS	0020	-0169	31369	2525			14367	799	107		015	013	027		

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Date Index	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6905 N	16505 W		233	95	10	16	214	1970	CSS	086	0021		00	0	X		X7	7	7		0044

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis Code	No. Obs. Depths	Special Observations
		08	S05	180	-155	-156	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STO	0000	-0166	3108	2502	0029499	0000	14361	804							
214		OBS	0000	-0166	31080	2502			14361	804	076		006	005	018		
214		OBS	0004	-0165	31111	2504			14362	807	077		005	006	018		
214		OBS	0009	-0173	31181	2510			14360	801	084		006	007	020		
		STO	0010	-0172	3119	2511	0028635	0029	14361	799							
214		OBS	0014	-0170	31219	2513			14363	795	087		007	007	021		
214		OBS	0018	-0171	31236	2514			14363	797	089		007	008	021		

Reference Ctry Code	Reference ID No.	Ship Code	Latitude ° 1/10	Longitude ° 1/10	Date Index	Marsden Square 10°	Marsden Square 1°	Station Time (GMT) Mo	Day	Hr. 1/10	Year	Originator's Cruise No.	Originator's Station Number	Depth to Bottom	Max. Depth of S'mpl's	Wave Observations Dir.	Hgt	Per	Sea	Weather Code	Cloud Codes Type	Amt		NODC Station Number
31	1706	GL	6904 N	16536 W		233	95	10	17	011	1970	CSS	087	0021		00	0	X		X7	7	8		0045

Water Color Code	Water Trans. (m)	Wind Dir.	Wind Speed or Force	Barometer (mbs)	Air Temp. °C Dry Bulb	Air Temp. °C Wet Bulb	Vis Code	No. Obs. Depths	Special Observations
		08	S04	162	-128	-129	7	05	

Messenger Time Hr 1/10	Cast No.	Card Type	Depth (m)	T °C	S ‰	Sigma-T	Specific Volume Anomaly	ΣΔD Dyn. M. x 10³	Sound Velocity	O_2 ml/l	PO_4-P µg-at/l	Total-P µg-at/l	NO_2-N µg-at/l	NO_3-N µg-at/l	SiO_4-Si µg-at/l	pH	SCC
		STO	0000	-0168	3120	2512	0028573	0000	14361	814							
011		OBS	0000	-0168	31200	2512			14361	814	071		004	003	021		
011		OBS	0005	-0165	31198	2511			14364	812	070		002	005	021		
		STD	0010	-0170	3119	2510	0028671	0028	14362	812							
011		OBS	0010	-0170	31186	2510			14362	812	068		003	004	022		
011		OBS	0015	-0168	31192	2511			14364	813	068		002	004	021		
011		OBS	0018	-0169	31191	2511			14364	817	069		003	005	021		

REFERENCE CTRY CODE	ID. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	QUADRANT	MARSDEN SQUARE 10°	1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	STATION NUMBER	DEPTH TO BOTTOM M	MAX. DEPTH OF SMPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
31	1706	GL	6854 N	16640 W		233	86	10	17	177	1970	CSS	090	0044		00	0	X		X1	6	4		0046

WATER COLOR CODE	TRANS. (m)	WIND DIR.	SPEED OR FORCE	BARO-METER (mbs)	AIR TEMP. °C DRY BULB	WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		14	S05	150	-083	-083	7	06	

MESSENGER TIME HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY	Σ ΔD DYN. M. x 10³	SOUND VELOCITY	O₂ ml/l	PO₄-P µg-at/l	TOTAL-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SIO₄-Si µg-at/l	pH	ICC
		STO	0000	-0097	3070	2470	0032568	0000	14388	788							
177		OBS	0000	-0097	30700	2470			14388	788	093		006				
177		OBS	0008	-0093	30701	2470			14391	792	098		007				
		STO	0010	-0092	3071	2470	0032477	0032	14392	790							
177		OBS	0016	-0048	30744	2472			14414	786	097		006				
		STO	0020	0051	3088	2478	0031723	0064	14462	768							
177		OBS	0024	0111	30973	2483			14492	758	091		008				
		STO	0030	0113	3097	2483	0031278	0096	1449[illegible]	761							
177		OBS	0032	0113						761	111		010				
177		OBS	0041	0110	30976	2483			14494	761	104		015				

REFERENCE CTRY CODE	ID. NO.	SHIP CODE	LATITUDE ° 1/10	LONGITUDE ° 1/10	QUADRANT	MARSDEN SQUARE 10°	1°	STATION TIME (GMT) MO	DAY	HR. 1/10	YEAR	ORIGINATOR'S CRUISE NO.	STATION NUMBER	DEPTH TO BOTTOM M	MAX. DEPTH OF SMPL'S	WAVE OBSERVATIONS DIR.	HGT	PER	SEA	WEATHER CODE	CLOUD CODES TYPE	AMT		NODC STATION NUMBER
31	1706	GL	6854 N	16724 W		233	87	10	17	237	1970	CSS	091	0046		00	0	X		X2	7	8		0047

WATER COLOR CODE	TRANS. (m)	WIND DIR.	SPEED OR FORCE	BARO-METER (mbs)	AIR TEMP. °C DRY BULB	WET BULB	VIS. CODE	NO. OBS. DEPTHS	SPECIAL OBSERVATIONS
		04	S07	127	-041	-042	7	06	

MESSENGER TIME HR 1/10	CAST NO.	CARD TYPE	DEPTH (m)	T °C	S ‰	SIGMA-T	SPECIFIC VOLUME ANOMALY	Σ ΔD DYN. M. x 10³	SOUND VELOCITY	O₂ ml/l	PO₄-P µg-at/l	TOTAL-P µg-at/l	NO₂-N µg-at/l	NO₃-N µg-at/l	SIO₄-Si µg-at/l	pH	ICC
		STO	0000	-0069	3067	2466	0032886	0000	14401	784							
237		OBS	0000	-0069	30668	2466			14401	784	091		006				
237		OBS	0008	-0062	30672	2466			14405	784	081		007				
		STO	0010	-0062	3067	2466	0032859	0032	14406	786							
237		OBS	0016	-0062	30678	2467			14407	786	090		007				
		STO	0020	-0019	3073	2469	0032590	0065	14428	780							
237		OBS	0024	0022	30789	2473			14449	775	090		007				
		STO	0030	0080	3092	2481	0031493	0097	14478	770							
237		OBS	0036	0127	31080	2491			14502	766	086		009				
237		OBS	0043	0169	31288	2505			14525	742	100		010				

Preliminary Results of Geologic Studies in the Eastern Central Chukchi Sea[1]

PETER W. BARNES [2]

INTRODUCTION

During late September and October 1970, the U.S. Geological Survey participated in the Western Beaufort Sea Ecological Cruise aboard the U.S. Coast Guard icebreaker GLACIER, in the eastern central Chukchi Sea. Seventy stations were occupied for geological sampling purposes (fig. 1). These studies were undertaken primarily to provide background data for interpreting ecological relationships, to locate and define these relationships, and to outline the processes of sediment transport and deposition. This report will deal with the first and third aspects of the overall program.

Considerable knowledge of the geology of the Chukchi Sea existed prior to the 1970 cruise of the GLACIER. Moore (1964) and Grantz and his co-workers (1970) studied the bottom geology and found only a thin sedimentary cover overlying rocks that extend west from the Prudhoe Bay and Naval Petroleum Reserve geologic provinces. The surficial sediments, morphology, and currents have been the subject of studies by the Navy and the University of Washington during their extensive investigations of the Bering and Chukchi Seas (Dietz and others, 1964; Fleming and Heggarty, 1966; Creager and McManus, 1967; McManus and others, 1969). Studies have indicated a shelf of low relief with a broad north-south trending trough 50 meters deep between the mainland and Herald Shoal. Relict and residual sediments dominate the area owing to minimal local sediment contribution and to sporadic northward currents that introduce material from outside the region (McManus and others, 1969).

Sampling on this cruise focused on sediment-transport processes with near-bottom current measurements and water-column turbidity determinations, supplemented by suspended sediment measurements made at the same time by the University of Alaska (see Naidu and Sharma, this Oceanographic Report).

METHODS

Current measurements were made with a film recording Savonius-type meter, accurate to 0.05 knots but readable to 0.01 knots. The sensor was deployed 1.5–2 meters above the bottom while at anchor. A 3-meter chain pendant below the meter served to dampen oscillations. The meter recorded for periods of up to 35 hours at 12 locations (fig 1 and table I, appendix A). Due to the movement of the ship at anchor and the resultant introduction of artificial currents, data were analyzed by vector summation. Sequential current speeds and directions were vectorially added, and the vectors generated by this summation were used in reporting the currents for the interval summed.

Bottom samples were obtained with a 10-gallon Van Veen grab except when ship motion or bottom conditions necessitated the use of a Shipek grab. Additional samples were obtained with a modified Reineck box corer with box dimensions of 20 × 20 × 60 cm, and a Hydro plastic corer rigged either as a gravity or a piston corer. All sediment samples were stored at 3–5° C prior to analysis (see Bouma, 1969, p. 313, 317, 332, for discussion of these sampling devices).

Textural analysis involved standard techniques. Sieves were used for gravels and sands and hydrometer for silt- and clay-sized materials. Box cores were extruded laterally from one side of the box and sliced vertically into 1–2 cm slabs, then placed on a Plexiglas sheet and radiographed using techniques outlined by Bouma (19t.).

[1] Publication authorized by the Director, U.S. Geological Survey.

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Water-clarity data were gathered with a 26-cm Secchi disk and a prototype transmissometer-depth sensor coupled to an x-y recorder. Calibration of the transmissometer was often problematical, particularly during the later part of the cruise when temperatures were colder. Bottom photographs were taken at selected stations in black and white and color. These photographs were used to supplement water clarity and sediment data.

Splits of four samples were frozen immediately after collection and sent to the U.S. Geological Survey's Organic Geochemistry Laboratory in Denver, for analysis of hydrocarbon content. The analyses for mercury, arsenic, copper, lead, and zinc were made on air-dried splits, using techniques outlined by Ward and others (1963), Vaughn and McCarthy (1964), and Ward and others (1969). The detection limit of these techniques is 0.010 parts per million (ppm) for mercury, 10 ppm for arsenic, and 5 ppm for copper, lead, and zinc.

RESULTS AND DATA

Currents

Near-bottom currents during September and October 1970 were dominated by northeast-southwest components of low to moderate velocities (fig. 2 and table I, appendix A). Bottom-current measurements in the northern and eastern sections of the study area, all in water depths less than 30 meters, showed a considerable range in velocity and direction. The data were not synoptic, because the observations were spread over a 23-day period. Consequently, some of the variability may be due to temporal and transient changes in the current regime.

Although many of the bottom photos were clouded by particulate matter, almost all revealed the absence of current-related features (fig. 3a). The exception was station 87, northeast of Cape Lisburne, where a current parallel to shore was indicated by northwest-trending ripple marks (fig. 3b).

On the northwest-southeast transect from stations 49 through 60 a central region of strong northward flow was bordered inshore and offshore by regions with southward currents. Velocities on this section, from 0.05 to 0.35 knots, were strongest to the north.

An inshore southward flow and an offshore northward flow were also found by Fleming and Heggarty (1966) at 20 meters in this same general area in August 1960. The velocities they recorded (0.1–0.7 knots) were generally higher than those reported here. These discrepancies may be partly due to differences in current meters and in depth of measurements. They used an Ekman-type meter which was placed farther above the bottom than our meter.

Currents, both at 10 meters and near the bottom trended with the wind vectors (Ingham and Rutland, this Oceanographic Report, figs. 32 and 75) at most stations; this relationship appeared strongest for the 10-meter measurements, and was most evident for stations 54 through 60 (figs. 1 and 2). At stations 54 and 55, weak winds were accompanied by moderate to strong northward 10-meter and bottom currents (0.15–0.35 knots). Strong northeasterly winds deflected the 10-meter current to the west at stations 59 and 60. Near-bottom currents were deflected to a lesser degree at station 59 and little or not at all at station 60.

Turbidity

Water-clarity data at 10 meters were virtually the same as surface values at individual stations and are more reliable instrument readings. Therefore, the 10-meter values were used for plotting purposes and will be considered representative of the turbidity distribution in the upper 10 meters of the water column. The data are assumed to be synoptic, although some observed differences probably reflect temporal variations during the 25-day period of observation.

Light-transmission values at 10 meters indicate a northwestward increase in water clarity (fig. 4). The clearer waters were associated with higher salinity values and the edge of the pack ice (see Ingham and Rutland, this Oceanographic Report, figs. 6 and 11). Water was more turbid and less saline to the south and in the shallower parts of the bight between Cape Lisburne and Icy Cape.

Bottom photos in the region of higher surface turbidity are somewhat fogged by particulate matter (fig. 3), although large objects such as ripples and starfish are discernible. Turbidity generally showed a pronounced in-

crease near the bottom of the water column. The thickness of this turbid layer was mapped (fig. 5). It was thickest over the deepest part of the depression between Herald Shoal and the mainland. Although turbid water was present over much of the inshore area shallower than 30 meters, the distinct layering found in deeper water was absent.

Sediments

Sediments ranged from muddy gravels to well-sorted sands (fig. 6). Particle-size determinations showed the following six types of deposits in a distribution similar to that reported by McManus and others (1969):

1. Moderately to well-sorted sand, distributed to 90 km from Point Lay and farther offshore at the northern end of the trough between Herald Shoal and the mainland.
2. Silt and clay (mud) along the eastern side of the offshore depression.
3. Muddy gravel on the east flank of Herald Shoal.
4. Sandy gravel north and east of Cape Lisburne. The gravel fraction consisted largely of clasts with very angular and fragile shapes and pebbles of uniform lithology, all of which indicate minimal waterborne transport and mixing.
5. Admixtures of items 1 through 4.
6. Sand and gravel on the modern beach almost devoid of fine material. Well-rounded pebbles were randomly distributed in all sediment types.

The occurrence of offshore gravel cannot be accounted for by modern processes. The fragile shapes and angularity of individual clasts, and the uniform lithologies of the gravel samples, indicate only minimal transport from the source areas and may indicate proximity to sea-floor outcrops (McManus and others, 1969).

Studies of subsurface sedimentary features and the use of radiographic techniques showed intensive bioturbation (fig. 7). Numerous worm tubes, burrows, and even individual worms were found during sectioning and examination (fig. 8). Other sediment-disrupting organisms encountered included echinoids, mollusks, gastropods, and walrus. The radiographs also show that rounded pebbles were randomly distributed.

Coastal Observations

Some coastal observations which relate to the problem of sediment supply and transport along the shore were made on the barrier island near Point Lay. During October, the seaward beaches of the barrier island at Point Lay consisted of a series of small (0.1 to 1 meter) asymmetrical ice-gravel ridges. These appear to have formed since the onset of winter by freezing at higher stands of the sea (fig. 9). For a distance of 1 km from the northern tip of the barrier island, a series of larger (1–3 meters) more symmetrical ridges occurred at higher elevation (figs. 9 and 10). These apparently mark former locations of the lagoonal opening and suggest a northward migration of sediments along the barrier island. Five samples from this island consist of a mixture of sand and gravel (fig. 6).

Sediment Transport Regime

Current directions, orientation of ripples northeast of Cape Lisburne, and the apparent displacement of a turbid layer eastward toward Point Lay suggest a clockwise eddy in the near-bottom water: circulation similar to that described by Fleming and Heggarty (1966). There is, however, apparently little deposition from the eddy, as the sandy bottom landward of the 40-meter contour does not show any increase in silt and clay content under the displaced turbid layer.

The turbid layer is thickest in the northwestern part of the study area, where water from the Bering Strait was found at depth (Ingham and Rutland, this Oceanographic Report). In studies of particle transport through the Bering Strait, 125 miles to the south, McManus and Smyth (1970) found high turbidity and relatively high concentrations of particulate matter throughout the water column. These data suggest that much of the suspended matter in the area could be derived from south of the Bering Strait.

When near-bottom current directions are superimposed on a profile of turbidity along a line between Cape Lisburne and Herald Shoal (fig. 11), northward vectors correlate with the most pronounced zone of turbid water along

the eastern side of the depression. In the western part of this transect, a southerly flow of less turbid water is indicated. The current and turbidity data suggest a net northward transport of fine-grained sediment from the Bering Sea toward the Arctic Ocean, with minimal deposition in the eastern central Chukchi Sea.

The sediment distribution pattern partly reflects the observed currents and water turbidity. Mud present along the eastern flank of the depression corresponds to the zone where the bottom turbid layer is thickest (figs. 5 and 11). To the west and east, possible relict or residual sand and gravel are present. Ice rafting appears to be only a minor source of sediment, and probably accounts for most of the rounded pebbles interspersed in the muds and sands offshore.

Geochemistry

Geochemical analyses of seven sediment samples from four locations in the Chukchi Sea (table III, appendix A) indicate a reducing sedimentary environment, except for the uppermost 1 or 2 cm. This conclusion is based on sediment color and the distribution of sulfur and organic components. The alkaline-soluble organic fraction was dominantly of the humic type and averaged about 0.5 percent of the total sediment, whereas the total organic content averaged 1.7 percent of the dry-sediment weight. The humic fraction, derived primarily from land plant detritus, indicates a terrestrial relict origin for the sediment, or a situation in which the contribution of terrestrial detritus masks the production of marine organic matter.

The bitumen (petroleum-like substances) content was relatively low, averaging only 0.005 percent. Analyses revealed a constancy of elemental abundances, with no abnormally high values for either the total sediment or the alkaline-soluble humic fraction (table III, appendix A). Although coal was present in the coarse fraction of several samples, it apparently was not a major organic constituent.

Mercury values averaged less than 0.02 ppm and ranged from below the limit of detection (0.01 ppm) to a maximum of 0.04 ppm (table II, appendix A). These are exceptionally low compared with concentrations in oceanic sediments elsewhere. In some areas, for example, average values range from 0.05 to 1.20 ppm (Fleischer, 1970). However, they are not unexpected, as there are no source areas of mercury nearby, and the organic content of the sediments is also relatively low.

Copper, lead, and zinc values also were low (table 1 and table II, appendix A), compared with marine sediments elsewhere (Turekian and Wedepohl, 1961). Arsenic values, however, averaged 24 ppm (table 1 and table II, appendix A)—high compared with normal values of 1–20 ppm (Wedepohl, 1969).

Table 1.—Selected elemental concentrations in sediment samples collected on 65 stations. (Analysis by Kam Leong, U.S. Geological Survey.)

Element	Average concentration, dry-sediment (ppm)	Range of concentation values (ppm)
Arsensic	24	<10–30
Copper	13	5–30
Lead	14	7–25
Zinc	59	25–160
Mercury	0.02	<0.01–0.04

CONCLUSIONS

1. The movement of fine-grained particulate matter involves transport toward the north along the eastern side of the trough bisecting the study area. Materials are transported from south of Cape Lisburne and from the coastal bight northeast of Cape Lisburne. Over shallower parts of the coastal zone an anticyclonic eddy and storms circulate and mix nearshore waters.

2. Beach processes were dominated by the formation of numerous ice-gravel ridges. These terrace-like ridges seem best explained by repeated changes of sea level due to storm surge and by concurrent freezing of shore-fast ice.

3. Gravel, gravel-mud, and gravel-sand found in much of this region reflect the fact that little or no sedimentation is going on. Along the eastern parts of the central trough, the presence of silty muds suggests sedimentation from the northward-flowing turbid layer. The lack of gravel in this area indicates that ice rafting is apparently not an important mode of sediment deposition.

4. Internal sediment structures caused by extensive bioturbation reveal that the sediments are heavily utilized by benthic fauna.

5. Geochemical studies showed no evidence of mercury or petroleum pollution and suggested no anomalous values of other elements. The organic fraction was dominated by land-derived plant debris.

ACKNOWLEDGMENTS

I wish to express my appreciation for the efforts of my fellow scientists, Captain Roberge, and the officers and crew aboard the GLACIER, without whose efforts this study could not have been conducted. Vernon E. Swanson performed the organic geochemical analysis; Kam Leong determined the heavy metal contents in the surface sediments.

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Wedepohl, K. H., ed., 1969, Handbook of geochemistry, Vol. II/1, Springer-Verlag, Berlin, p. 33.

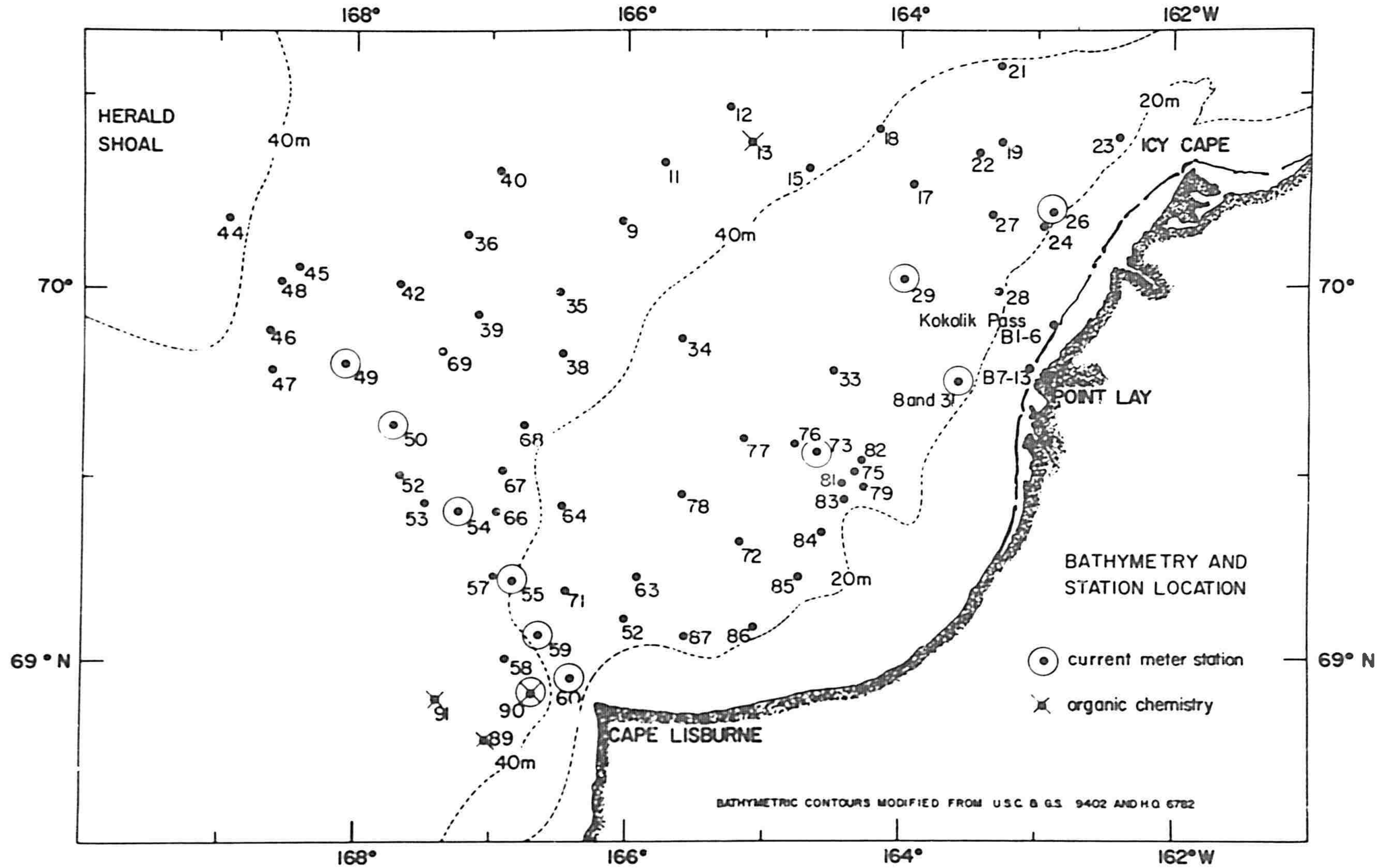

Figure 1.—Location map, sampling sites, and bathymetry of area studied. B1-13 are samples taken on the Barrier island off Point Lay, Alaska.

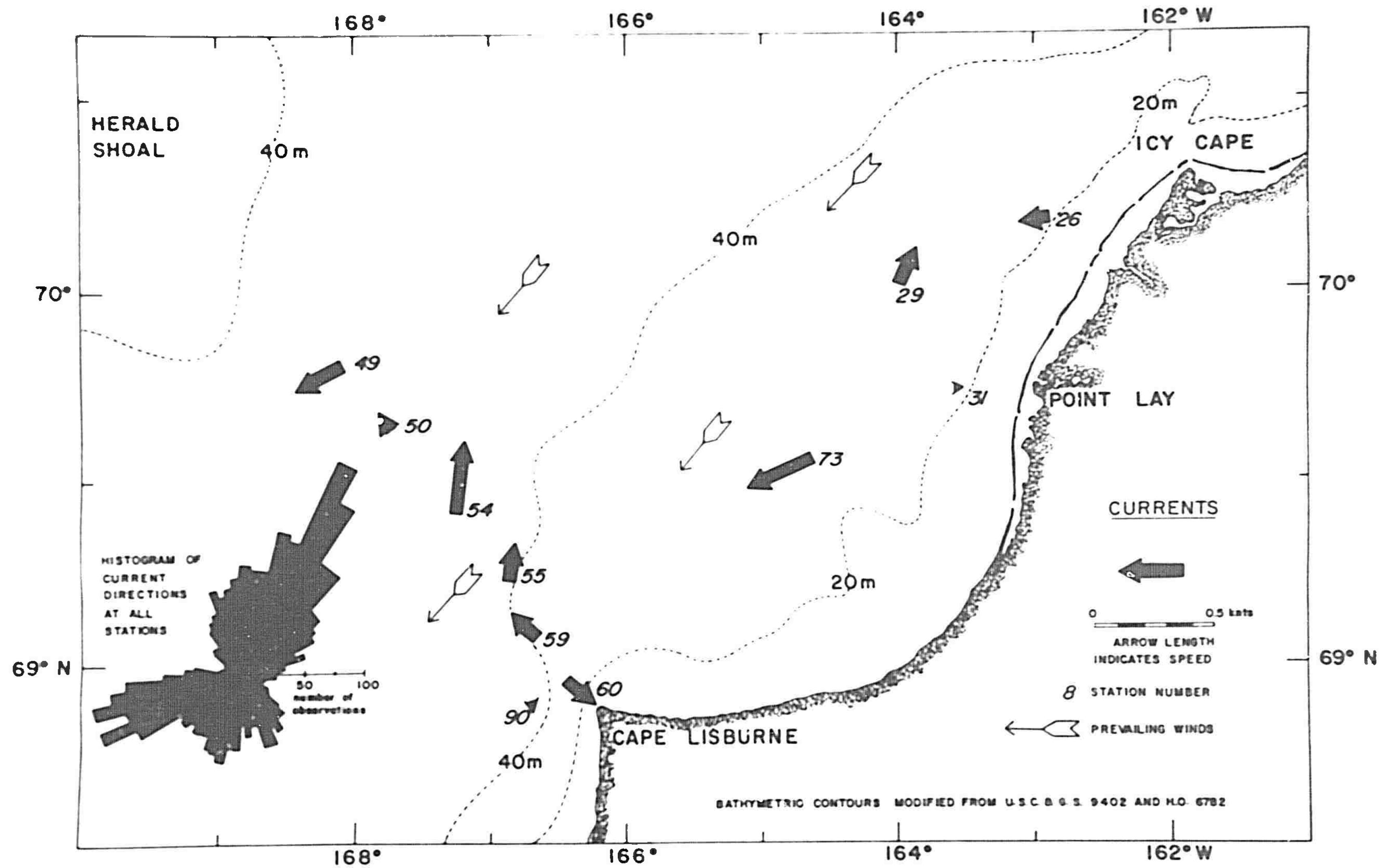

Figure 2.—Direction and velocity of near-bottom currents as determined by vector summation of current meter data.

Figure 3a.—Bottom photograph at station 63. Compass card is 4 cm in diameter. Note turbidity at this station over a mud-sand bottom.

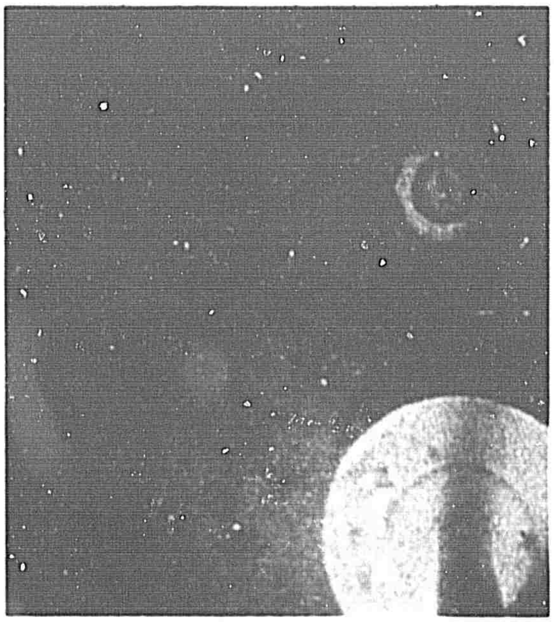

Figure 3b.—Bottom photograph at station 87. Scale same as 3a. Note the ripple marks in sandy gravel substrate.

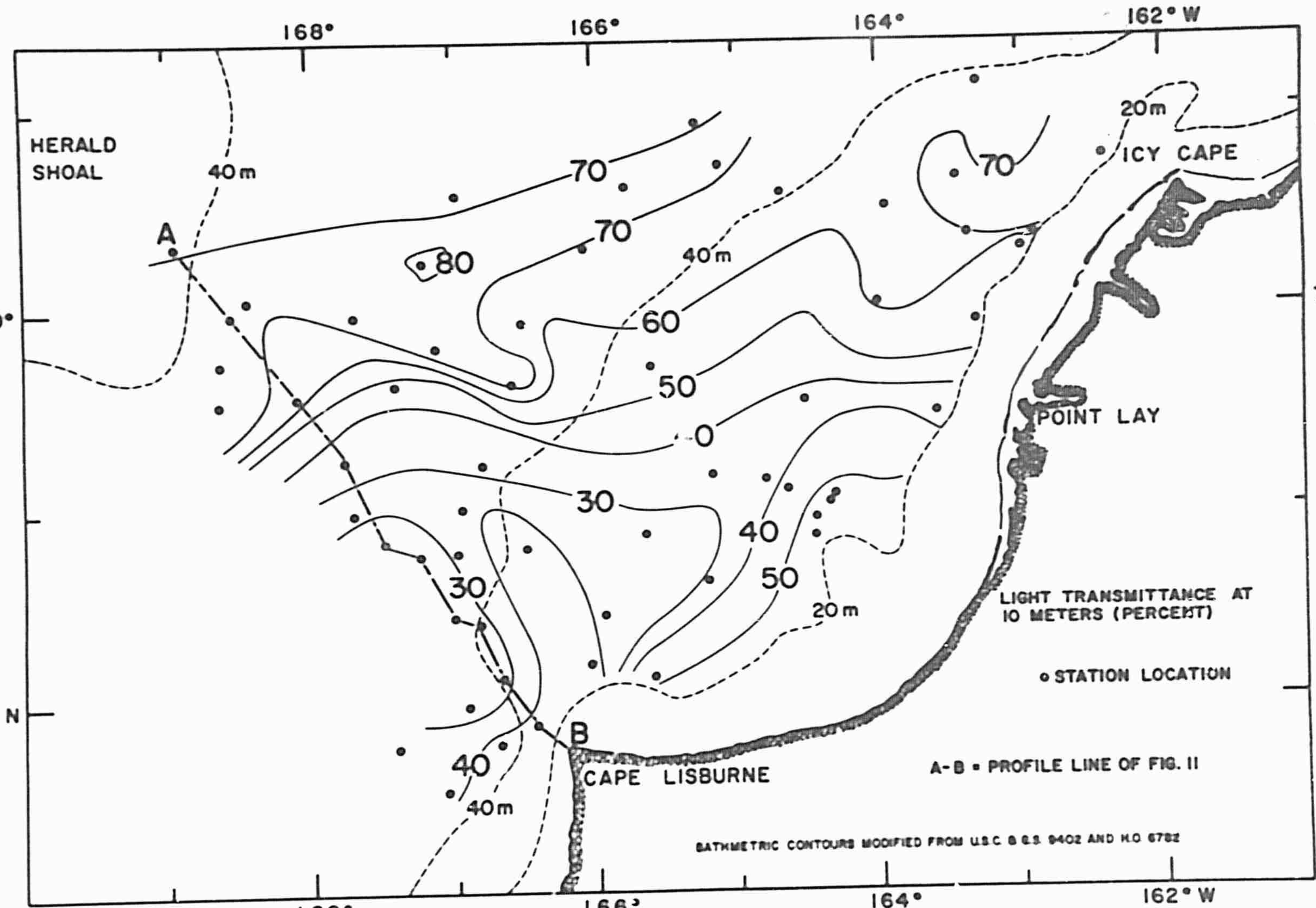

Figure 4.—Light transmittance at 10-meter depth. Values are given as percent of clear water. Line A-B is location of transmittance and current profile of Figure 11.

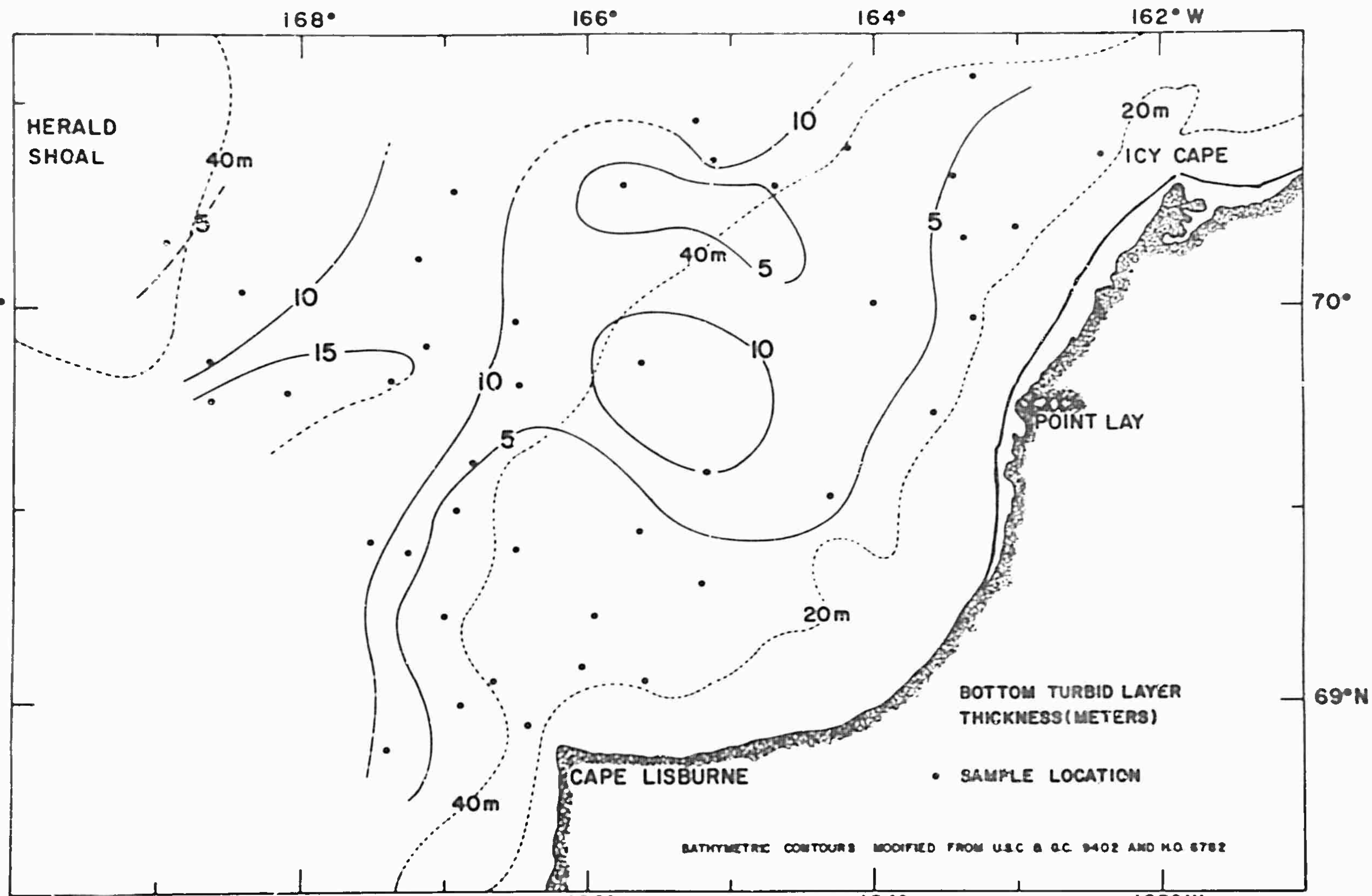

Figure 5.—Thickness of bottom turbid layer (m). Note eastward displacement of layer off Point Lay.

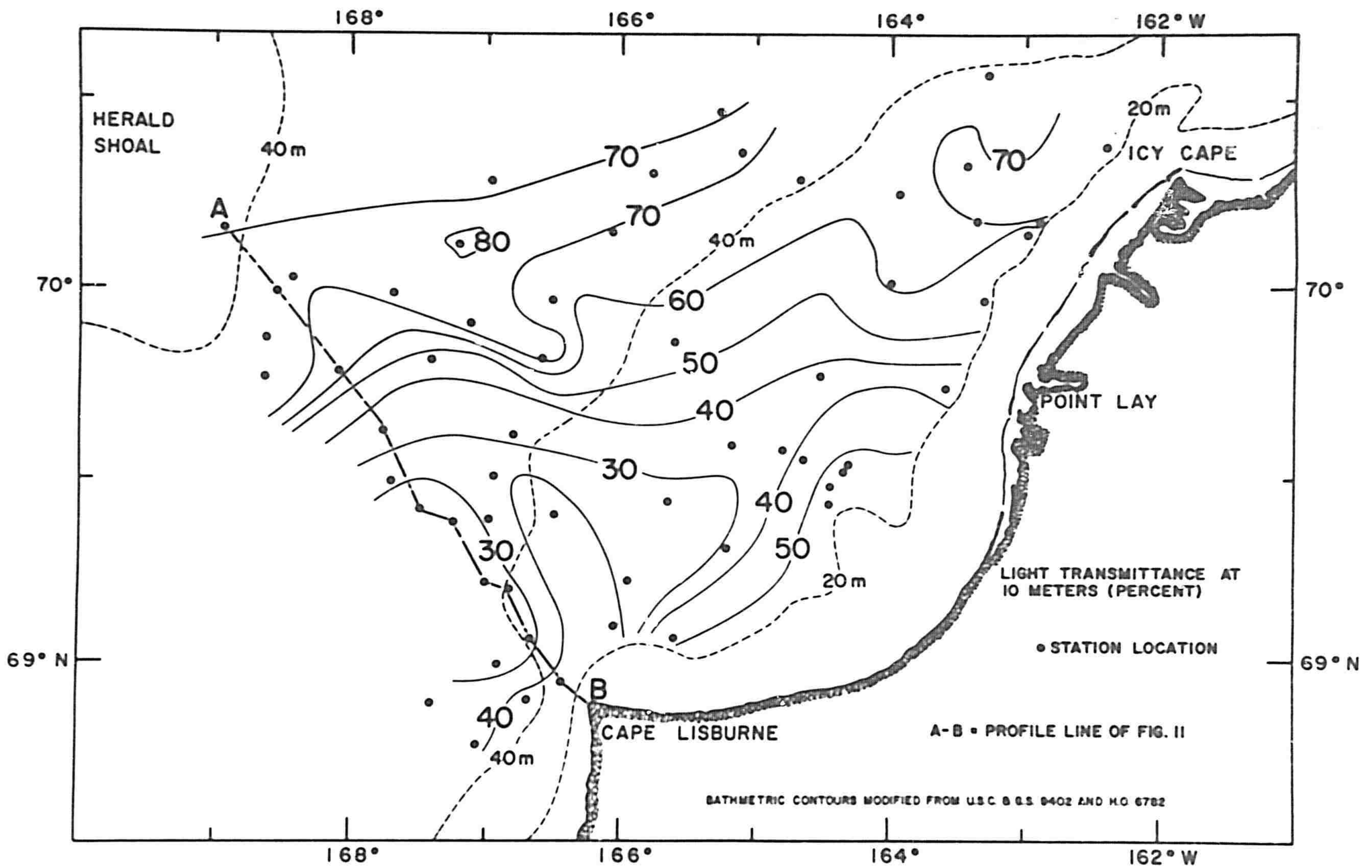

Figure 4.—Light transmittance at 10-meter depth. Values are given as percent of clear water. Line A–B is location of transmittance and current profile of Figure 11.

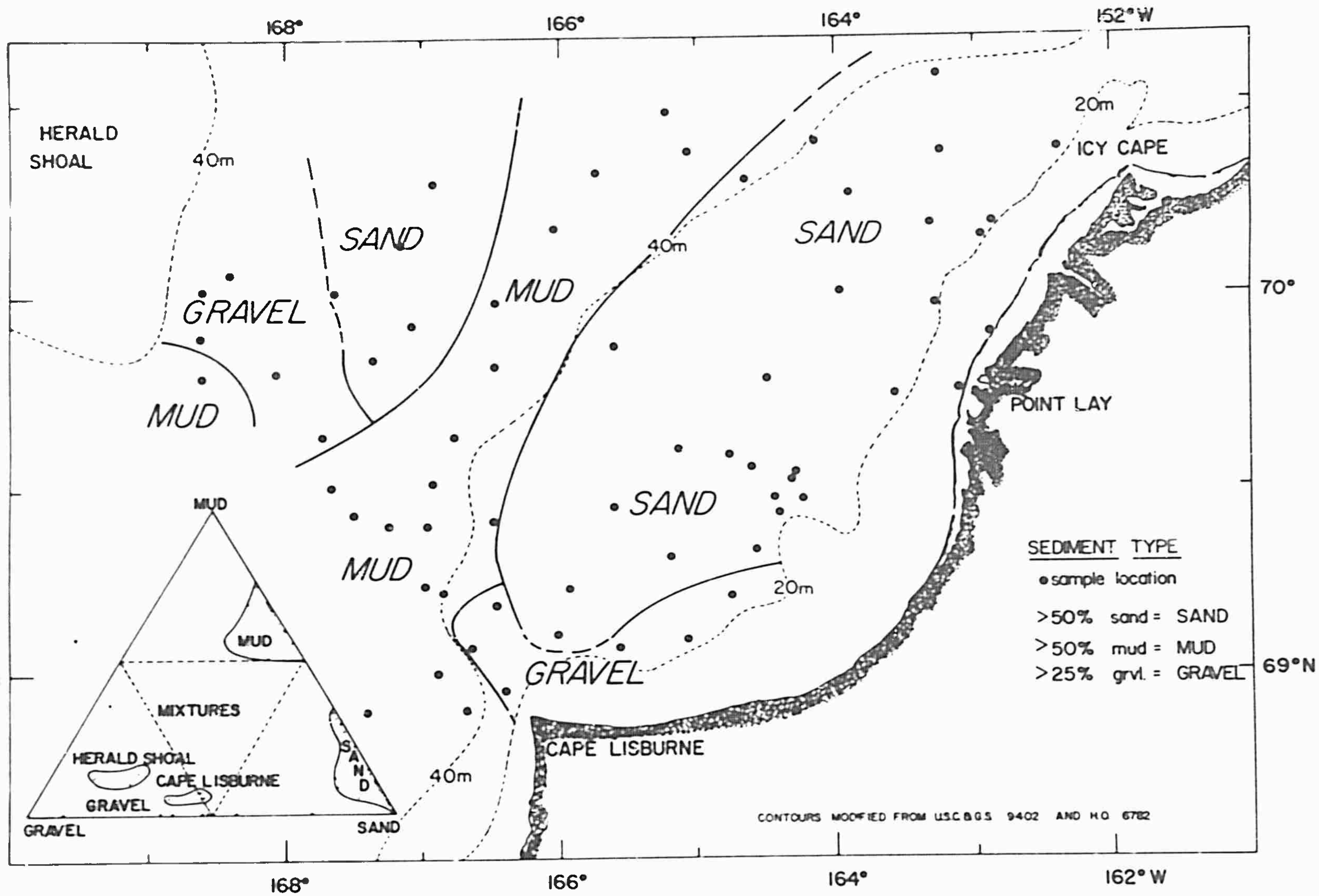

Figure 6.—Bottom sediment types. Gravel = >2 mm, sand = 2–0.62 mm, silt and clay (mud) = <.062 mm.

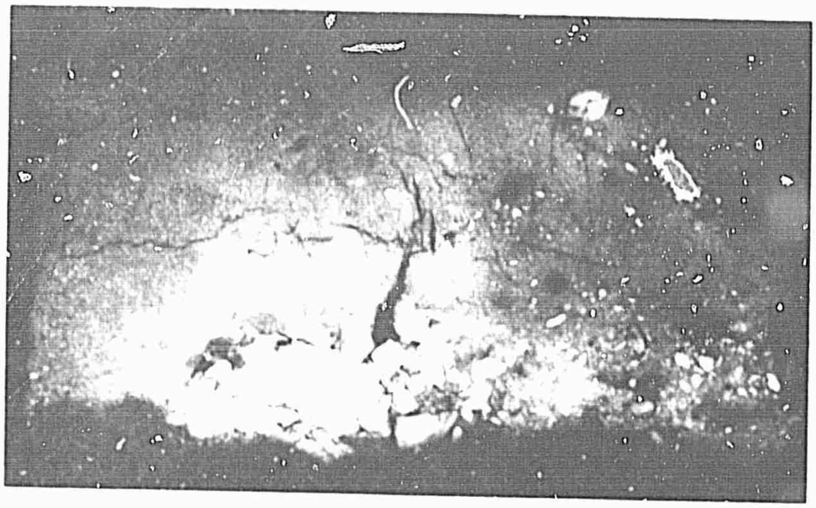

Figure 7a.—Radiograph of 1-cm thick slab of box core from station 79. Note worm tubes, rounded pebbles and shell material. The bottom of the core has higher sand and gravel content. The distance across the core is 30 cm.

Figure 7b. Radiograph of 1-cm thick slab of box core from station 9. Note abundant bioturbation and occasional pebbles. The distance across the core is 30 cm.

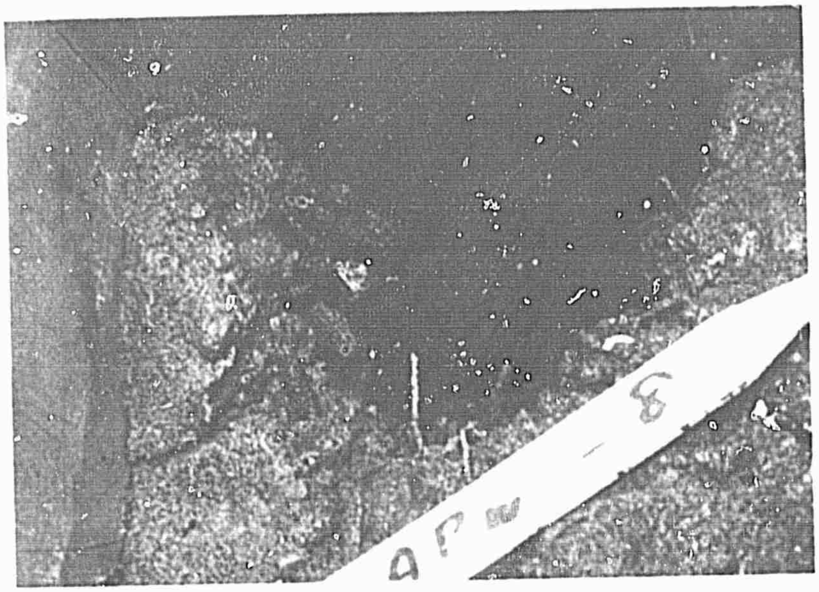

Figure 8.—Bioturbation in surficial sediments at station 8. Depression above the label is caused by water washing out of box core sampler. Label is 1.5 cm wide.

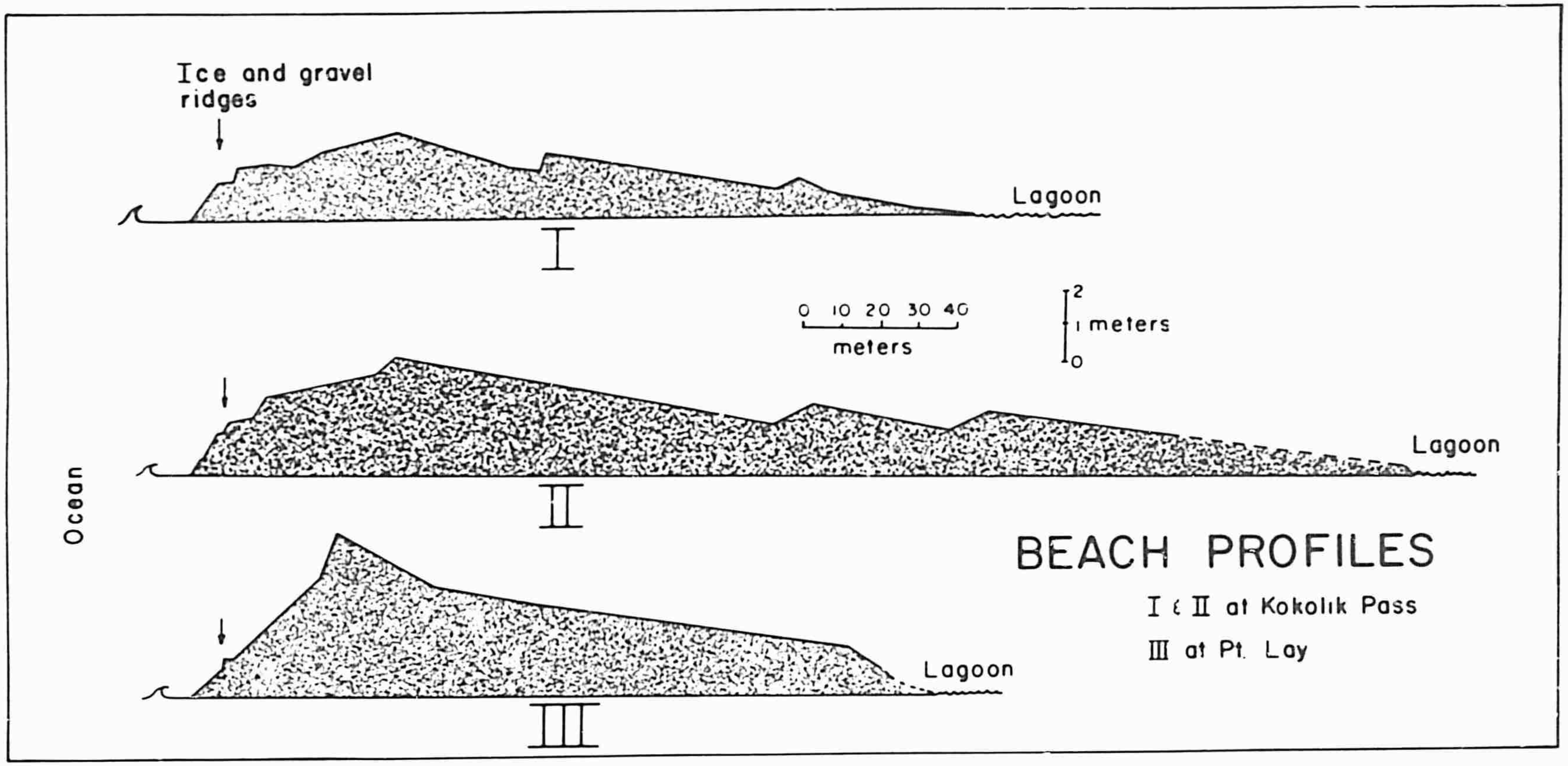

Figure 9.—Beach profiles I and II at Kokolik Pass (16 km north of Point Lay) and III at Point Lay. Note shoreline ice gravel ridges and numerous larger ridges on profiles I and II. Note decreased width and increased heights of Profile III.

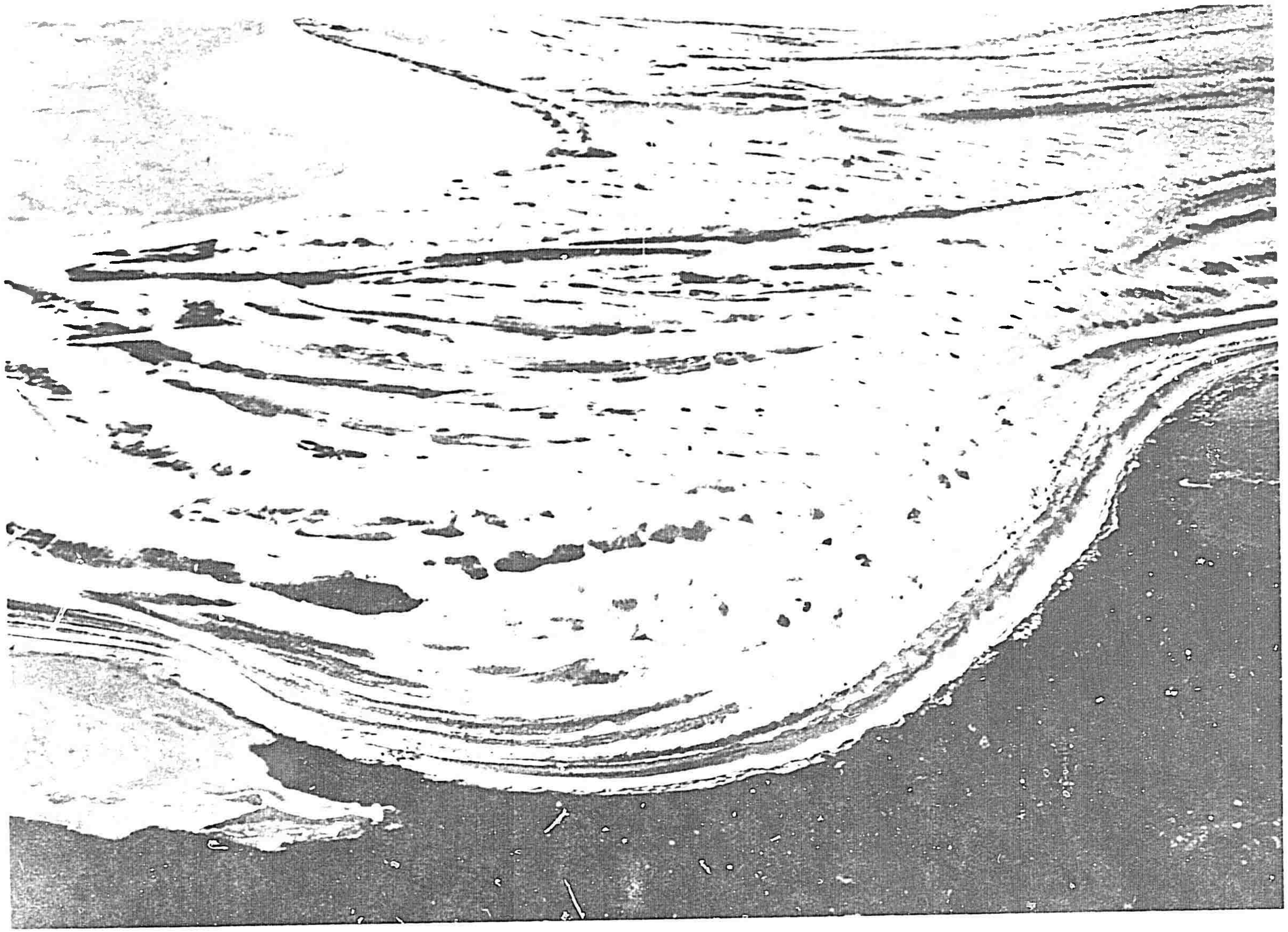

Figure 10.—Aerial view south from Kokolik Pass (16 km north of Point Lay), lagoon to left. Barrier island is about 200 m wide. Note the small "concentric" ice-gravel ridges near the shoreline and the succession of larger, older ridges showing northward growth of the island.

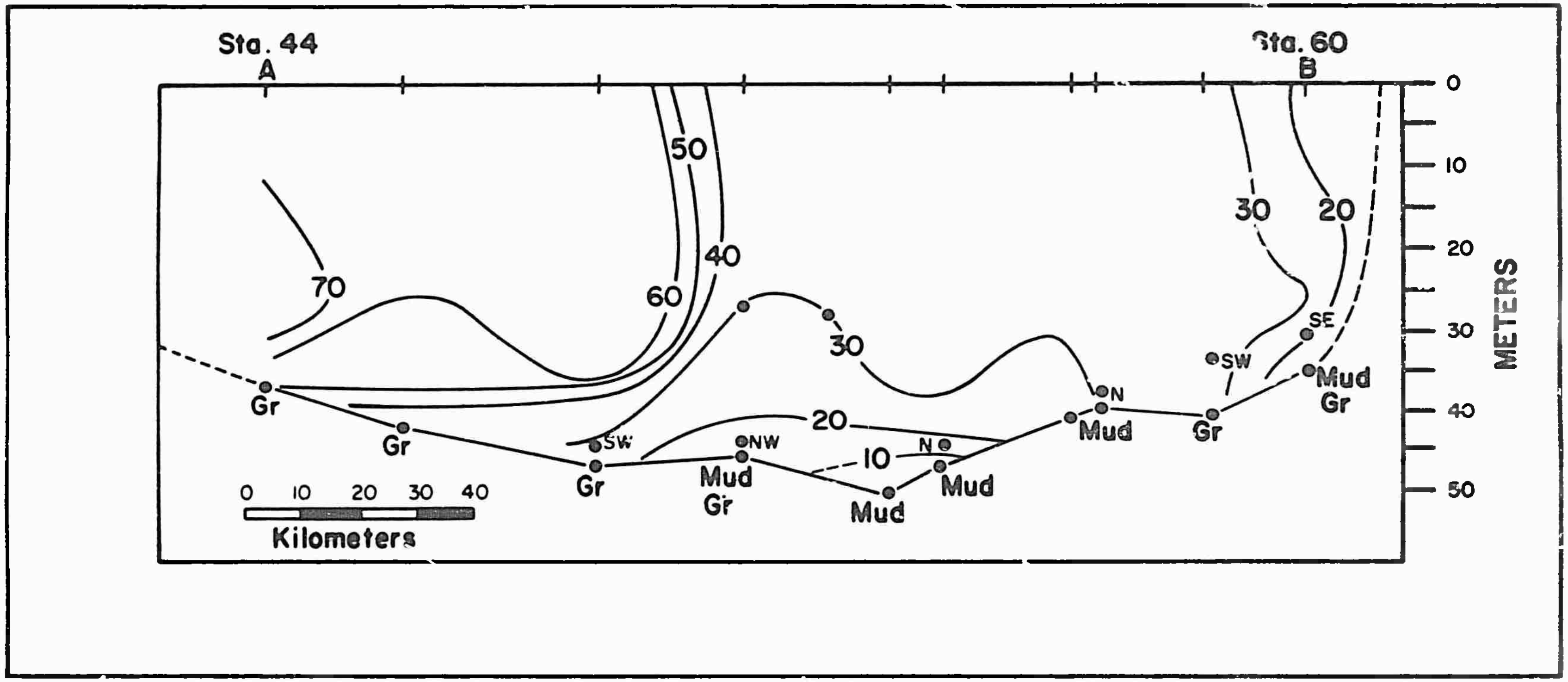

Figure 11.—Northwest-southeast profile showing transmittance (figures in percent), bottom-sediment type (Gr=Gravel, mud=silt and clay), and near-bottom current directions (NW=northwestward, etc., see Figure 4 for location).

Appendix A—Data

Table I.—Vector Sums of Currents, Eastern Central Chukchi Sea, Fall 1970

Station	Date (GMT)	Time meter started (GMT)	Current meter depth (meters)	Interval	Speed knots (see note [a])	Direction true (see note [b])
8	9/26	0430	17	24 hr– 0 min	0.08	007
8	9/27	0430	17	10 hr– 0 min	0.05	165
26	10/3	2015	18	7 hr–54 min	0.12	262
29	10/5	0230	19	2 hr–26 min	0.19	028
31	10/5	2215	18	6 hr–26 min	0.08	084
49	10/9	2015	47	1 hr–54 min	0.23	242
50	10/10	0230	45	2 hr–12 min	0.10	329
54	10/10	1800	45	1 hr–48 min	0.33	005
55	10/11	0100	38	5 hr–49 min	0.17	009
59	10/11	1715	33	1 hr–40 min	0.16	315
60	10/11	2315	30	4 hr–39 min	0.16	128
73	10/15	0215	25	49 min	0.32	243
90	10/17	1945	42	2 hr–15 min	0.05	179

Note:

[a] Accuracy of individual current speed readings is ±0.05 knots, but the instrument can be read to ±0.01 knots. This, in conjunction with the process of vector summation, allows speeds to be reported to the nearest 0.01 knot, although the accuracy is not increased.

[b] The resolution on both the vane and compass for individual directional observations is 2.8°.

Table II.—Summary of Station Data.

Station No.	Water depth (meters)	Geol. sample type, (see note [a])	Percent Gravel	Percent Sand	Percent Mud	Surface Transmittance (see note [b])	10 m transmittance	Turbid layer thickness (meters)	Bottom photo quality (remarks)	Arsenic (ppm)	Copper (ppm)	Lead (ppm)	Zinc (ppm)	Mercury (ppm)
8	21	Gr, BC, Tr, Cur	7.4	86.7	5.9	13	13	0	---	30	10	10	30	<0.01
9	44	Gr, BC, Tr, Cam	0	31.2	68.8	70	70	[c]	Bottom just visible.	30	15	25	80	0.01
11	43	Gr, BC, Tr, SC	0.1	30.9	69.0	73	73	3	---	30	20	20	90	0.02
12	44	Gr, BC, Tr	0	24.2	75.8	68	69	12	---	30	20	20	160	0.01
13	43	BC, Tr	0	30.4	69.6	71	73	11	---	30	25	15	90	<0.01
15	42	Gr, BC, Tr	0.2	68.2	31.6	63	64	5	---	30	15	10	60	0.03
17	36	BC, Tr	0.1	92.1	7.8	65	65	[c]	---	20	10	10	30	0.01
18	40	Gr, BC, Tr	0	84.6	15.4	60	61	7	---	30	10	15	35	<0.01
19	31	Gr, BC, Tr	0	95.4	4.6	70	68	[c]	---	20	10	10	30	0.01
21	38	Gr, Tr	0	89.9	10.1	66	69	3	---	20	10	10	35	<0.01
22	30	Tr	---	---	---	73	76	5						
23	24	Gr, Tr, Cam	0	98.5	1.5	72	72	1	Bottom clear.	20	10	15	45	0.03
24	20	Gr, Tr, Cam	0	96.2	3.8	59	50	[c]	Bottom just visible.	20	10	10	40	0.02
26	18	Gr, Tr, Cam, Cur	0.3	97.4	2.3	72	71	0	Bottom just visible.	30	10	10	35	0.01
27	30	BC, Tr	0	95.7	4.3	69	70	0	---	30	10	25	50	<0.01
28	20	Gr, Tr, BC, Cam	0	94.9	5.1	58	57	4	Clear photos.	30	10	15	30	0.01
29	30	Tr, Cam, Cur, Gr, BC	0.1	90.8	9.1	63	65	7	Photo murky.	30	10	10	35	<0.01
31	20	Gr, Tr, Cam, Cur	2.3	86.9	10.8	39	38	3	Photos clear.	30	10	10	45	0.03
33	30	Gr, Tr	2.8	91.9	5.3	34	34	[c]	---	20	10	15	40	0.03
34	43	Gr, Tr, Cam, SC	0.3	66.5	33.2	55	56	12	Photos murky.	30	15	20	60	0.01
35	42	Gr, Tr	0	39.7	60.3	60	61	9	---	30	15	15	100	0.02

Table II.—(Continued)

Summary of Station Data

Station No.	Water depth (meters)	Geol. sample type, (see note (*))	Percent Gravel	Percent Sand	Percent Mud	Surface Transmit-tance (see note (b))	10 m transmit-tance	Turbid layer thick-ness (meters)	Bottom photo quality (remarks)	Arsenic (ppm)	Copper (ppm)	Lead (ppm)	Zinc (ppm)	Mercury (ppm)
36	48	Gr, Tr, SC	2.2	65.8	32.0	79	80	12	----------	30	15	10	80	0.02
38	44	Gr, Tr, Cam	0.2	39.5	60.3	70	71	6	Photos murky.	30	15	10	85	0.01
39	51	Gr, Tr	21.9	48.9	28.3	77	78	12	----------	25	12	8	60	---
40	48	Gr, BC, Tr, Cam	0.1	77.6	22.3	69	69	13	Photos murky.	30	10	10	40	0.01
42	52	Gr, Tr, Cam, SC	18.1	41.6	40.3	73	72	(*)	Bottom visible.	25	12	12	80	<0.01
43	46	Gr, BC, Tr, Cam	75.7	12.6	11.6	71	71	8	Bottom clear.	10	5	13	30	0.02
44	37	Gr, BC, Tr, Cam	66.9	22.4	10.8	70	69	4	Botton clear.	10	7	7	35	0.02
46	45	Gr, Tr.	72.9	17.0	10.1	78	78	8	----------	8	7	7	30	0.02
47	54	Gr, Tr	9.6	39.6	50.3	78	78	18	----------	20	30	15	110	0.04
48	42	Gr, BC, Tr, Cam	63.3	26.5	10.2	62	62	(*)	Bottom clear.	11	9	7	35	0.01
49	47	Gr, BC, Tr, Cam, Cur	60.1	4.3	35.5	64	65	16	Bottom just visible.	10	14	8	60	0.01
50	46	Gr. Tr. Cam. Cur BC	28.1	27.6	44.3	32	31	(*)	Botton visible.	40	18	15	80	0.04
52	46	Gr, Tr	8.5	29.5	61.9	29	29	(*)	----------	30	20	20	110	0.03
53	51	Gr, Tr	6.1	24.8	69.1	33	33	11	----------	20	15	15	95	0.01
54	47	Gr, Tr, Cam, Cur	0.4	33.3	66.3	37	38	8	Photos murky.	20	15	20	85	0.02
55	40	Gr. Tr. Cam, Cur, BC	17.9	26.5	55.6	32	33	0	Bottom clear.	25	20	16	78	0.02
57	46	Gr, Tr	0.1	31.2	68.6	31	31	0	----------	30	15	15	80	0.01
58	46	Gr, Tr	0.6	32.0	67.4	38	37	0	----------	20	15	20	95	0.01
59	41	Gr, BC, Tr. Cam Cur	54.3	21.8	23.8	31	31	0	Bottom clear.	13	9	9	50	0.01
60	35	Gr, BC, Tr, Cam, Cur	29.7	29.8	40.5	21	20	3	Photos murky.	14	14	14	75	0.04

Table II.—(Continued)

Summary of Station Data

Station No.	Water depth (meters)	Geol. sample type, (see note (*))	Percent Gravel	Percent Sand	Percent Mud	Surface Transmittance (see note (*))	10 m transmittance	Turbid layer thickness (meters)	Bottom photo quality (remarks)	Arsenic (ppm)	Copper (ppm)	Lead (ppm)	Zinc (ppm)	Mercury (ppm)
62	28	Gr, Tr, Cam	0.7	96.5	2.8	11	8	0	Water clear no bottom.	30	10	15	25	<0.01
63	35	Gr, Tr, Cam	0.2	70.2	29.7	24	24	0	Bottom visible.	20	15	15	50	0.01
64	38	Gr, BC, Tr, Cam	0	48.7	51.3	16	16	0	Photo murky.	30	15	20	65	<0.01
66	46	Gr, Tr	0.8	43.6	55.6	25	25	(*)	---	30	20	15	75	<0.01
67	46	Gr, Tr	1.9	25.2	72.9	21	21	--	--- ---	30	30	20	100	0.01
68	45	Gr, Tr, Cam	0.2	36.7	63.1	31	31	8	Bottom visible.	20	20	20	85	<0.01
69	50	Gr, BC	17.2	54.8	28.0	41	44	16		25	12	16	61	0.01
71	44	Gr	24.6	Estimate 44.2	31.1			--	-	22	15	19	60	0.01
72	26	Gr, Tr, Cam	10.9	77.2	13.5	30	30	0	Bottom clear.	27	9	22	67	0.02
73	26	Gr, Tr, Cam, Cur	0.4	88.6	11.0	45	45	(*)	Bottom clear.	20	10	15	40	0.01
75	30	Gr, Tr	0	91.9	8.1	43	43	(*)		30	10	20	40	0.01
76	27	Gr, Tr	0.1	89.1	10.8	33	34	(*)		30	10	20	35	0.01
77	32	Gr, BC, Tr, Cam	2.7	80.1	17.2	39	39	10	Photos murky.	30	10	20	45	<0.01
78	34	Gr, BC, Tr	0.7	72.5	26.8	25	24	4		20	10	20	55	0.01
79	21	Gr, BC	2.2	90.8	7.0			-		30	10	20	45	0.02
81	28	Gr, Tr	0.3	86.1	13.6	52	52	(*)		30	10	15	40	<0.01
82	24	Gr, Tr	0.2	93.2	6.6	54	54	6		30	10	15	35	0.01
83	23	Gr, Tr	4.3	86.1	9.6	51	52	(*)		30	10	15	40	0.02
84	25	Gr	11.2	80.1	8.6			--		36	9	9	30	0.02
85	23	Gr	48.9	43.5	7.6			--		20	5	8	35	0.02
86	21	Gr	59.1	35.5	5.4			--	--- -- --	16	6	8	27	0.02
87	21	Gr, Tr, Cam, BC	49.0	45.8	5.2	47	48	0	Bottom clear, ripples, oriented northwest.	20	5	8	28	0.02
89	41	Gr, Tr, SC				26	24	(*)	---	--	-	-	-	--

Table II.—(Continued)

Summary of Station Data

Station No.	Water depth (meters)	Geol. sample type, (see note (a))	Percent Gravel	Percent Sand	Percent Mud	Surface transmittance (see note (b))	10 m Transmittance	Turbid layer thickness (meters)	Bottom photo quality (remarks)	Arsenic (ppm)	Copper (ppm)	Lead (ppm)	Zinc (ppm)	Mercury (ppm)
90	44	Gr, Tr, Cam, Cur, SC	6.1	27.7	66.2	17	17	(c)	Photos murky.	30	20	15	90	0.02
91	46½	Gr, BC, Tr	0.1	29.4	70.6	19	21	7	....	20	15	15	80	0.01
Beach Samples Point Lay														
B–1	—	....	23.0	76.8	0.2	--	--	--	Lagoonal Beach.	--	--	--	--	---
B–4	--	....	90.0	2.0	0	--	--	--	Beach Ridge.	--	--	--	--	---
B–5	—	....	99.9	0.1	0	--	--	--	Beach Ridge.	--	--	--	--	---
B–6	--	....	51.6	48.4	0	--	--	--	Back Beach.	--	--	--	--	---
B–7	--	....	61.0	39.0	0	--	--	--	Swash Zone.	--	--	--	--	---
B–10	--	....	99.6	0.4	0	--	--	--	Beach Ridge.	--	--	--	--	---
B–12	--	....	27.4	72.6	0	--	--	--	Back Beach.	--	--	--	--	---
B–13	--	....	50.7	49.2	0.1	--	--	--	Lagoonal Beach.	--	--	--	--	---

Notes on Table II:

(a) Gr = Grab (Van Veen or Shipek)
BC = Box Core
SC = Sigma Corer (small piston or gravity corer)
Tr = Transmissometer
Cam = Camera
Cur = Current Meter

(b) Transmittance is reported as percent (clear water = 100%) from a 1 meter beam path transmissometer. The instrument was not calibrated in the field, thus only relative differences should be considered meaningful.

(c) Indicates turbid layer, if present, is unclear, poorly defined or unsampled.

Table III.—Analyses of Bottom-Sediment Samples, Chukchi Sea*

Station Sediment type Sample depth	13 Silty clay 0–3 cm	13 Silty clay 15–25 cm	13 Silty clay 40–45 cm	89 Sandy silt 0–10 cm	90 Silty clay 0-10 cm	91 Silty clay 0–4 cm	91 Silty clay 5–10 cm
Carbon:							
Total	1.39	1.37	1.33	1.22	1 37	1.17	1.21
Mineral	.24	.21	.20	.34	.31	.22	.22
Organic	1.15	1.16	1.13	.88	1.06	.95	.99
Organic matter[1]	1.96	1.97	1.92	1.50	1.80	1.62	1.68
$CaCO_3$[2]	2.00	1.75	1.67	2.83	2.58	1.83	1.83
Sulfur:							
Total	.16	.17	.33	.18	.12	.20	.22
Free[3]	.0009	.0114	.0033	.0059	.0032	.0015	.0104
Bitumen	.0099	.0064	.0047	.0038	.0046	.0058	.0036
Humate[4]	.4728	.5738	.3931	.4755	.4685	.4046	.5114
Humic fract.	.1892	.3118	.2172	.2447	.2466	.1744	.2577
Fulvic fract.	.2836	.2620	.1759	.2308	.2219	.2302	.2537
Si	>10	>10	>10	>10	>10	>10	>10
Al	7	7	7	10	7	7	7
Fe	3	3	2	3	2	2	2
Mg	1.5	1.5	1.5	2	1	1	1
Ca	1.5	1.5	1.5	1.5	1	1	1
Na	3	2	1.5	2	1.5	2	2
K	3	3	2	3	2	2	3
Ti	.3	.3	.3	.3	.3	.3	.3
Mn	.03	.02	.02	.03	.02	.02	.03
B	.005	.005	.005	.005	.005	.005	.005
Ba	.05	.07	.05	.07	.07	.07	.07
Be	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Ce	.015	.015	.015	.015	.015	D	.015
Co	.0007	.001	.0007	.001	.001	.0007	.001
Cr	.007	.007	.007	.01	.007	.007	.01
Cu	.002	.0015	.0015	.0015	.0015	.001	.0015
Ga	.002	.002	.0015	.002	.0015	.0015	.002
La	.003	.003	.003	.003	.003	.003	.003
Ni	.002	.003	.002	.003	.003	.002	.003
Pb	.0015	.0015	.0015	.0015	.0015	.0015	.0015
Sc	.001	.001	.001	.001	.001	.001	.001
Sr	.015	.015	.001	.015	.015	.015	.02
V	.015	.015	.015	.01	.01	.01	.015
Y	.002	.003	.002	.002	.002	.002	.003
Yb	.0002	.0003	.0002	.0002	.0002	.0002	.0002
Zr	.01	.015	.015	.01	.015	.015	.01

TABLE III.—(Continued)

Analyses of Bottom-Sediment Samples, Chukchi Sea[*]

Station Sediment type Sample depth	13 Silty clay 0–3 cm	13 Silty clay 15–25 cm	13 Silty clay 40–45 cm	89 Sandy silt 0–10 cm	90 Silty clay 0–10 cm	91 Silty clay 0–4 cm	91 Silty clay 5–10 cm
Humic fract.:[4]							
Percent of organic matter	9.7	15.8	11.3	16.3	18.7	10.8	15.3
Percent of alkaline-soluble organic matter	40.0	54.3	55.3	51.5	52.6	43.1	50.4
Percent C	52.94	51.77	53.69	53.27	52.99	53.07	51.86
Percent H	6.32	6.23	6.32	6.14	5.98	6.31	6.13
Percent N	6.05	5.55	5.37	5.60	5.50	6.09	5.34
Percent ash	10.89	15.59	14.63	9.22	9.71	7.96	11.64
Percent of ash:							
Fe	1.5	1.	1.5	1.5	.3	2.0	.3
Mg	.07	.05	.07	.05	.02	.07	.02
Ca	.05	<.05	<.05	.05	<.05	<.05	<.05
Ti	.02	.02	.15	.2	.05	.2	.02
Mn	.007	.003	.005	.015	.01	.015	.002
Ag	.0001	.00015	.0001	.00015	.00007	.0001	.0001
B	.02	.007	.007	.007	.005	.007	.007
Ba	.002	.001	.002	.002	.001	.005	.0005
Be	.00007	.0015	.00015	---	---	---	---
Co	.005	.002	.007	.005	.007	.007	.002
Cr	.007	.01	.015	.015	.007	.01	.007
Cu	.1	.07	.1	.15	.07	.1	.07
Mo	.002	.007	.02	.01	.005	.007	.007
Ni	.007	.007	.01	.015	.005	.015	.01
Pb	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Sr	.001	.001	.0015	.0015	.0015	.0015	<.001
V	.015	.015	.02	.03	.02	.01	.015
Zn	.015	.01	.015	.015	.01	.015	.01
Zr	<.002	—	<.002	.003	--	.005	---

[*] Data supplied by V. E. Swanson, T. C. Geng, and A. H. Love, U.S. Geological Survey.
[1] Organic matter calculated as 1.7 x organic carbon.
[2] Calcium carbonates calculated as 8.33 x mineral carbon.
[3] Benzene-soluble sulfur.
[4] Alkaline-soluble humic substances, sum of humic and fulvic fractions; reported on ash-free basis.
[5] Calculations as percent of total organic matter and as percent of alkaline-soluble organic matter are on ash-free basis. Analyses for carbon, hydrogen, and nitrogen are also on ash-free basis.

Pelagic Bird and Mammal Observations in the Eastern Chukchi Sea, Early Fall 1970

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INTRODUCTION

The Smithsonian Institution was invited to make marine bird and mammal observations during a U.S. Coast Guard ecological cruise off the north slope of Alaska in early fall, 1970. The purpose of the cruise was to gather baseline data on the marine ecosystem in order to evaluate the effects of pollution which may occur as a consequence of development of the Alaskan north slope. The icebreaker GLACIER was deployed to the Beaufort Sea from 22 September to 18 October for the cruise. Ice conditions in the western Beaufort Sea proved so heavy in late September, however, that it was decided to investigate an alternate area in the eastern Chukchi Sea from Icy Cape to Cape Lisburne. This region may likewise be developed for its mineral and petroleum resources. The change in area of study proved a happy one ornithologically since little was previously known of pelagic bird distribution in the Chukchi and our fall, at-sea observations are the latest in the season for the area. This preliminary report on the pelagic birds and mammals is intended to present distributional and feeding data and to relate them to the presence of ice and the timing of migration. The preponderance of information collected dealt with birds reflecting both the authors' field of specialization and the relative abundance of observations.

PREVIOUS STUDIES ON MARINE BIRDS AND MAMMALS

The lack of shipping routes through the Chukchi Sea has limited knowledge of the distribution and abundance of pelagic birds for this area. There are only three published accounts of extensive at-sea observations. E. W. Nelson (1883) entered the Chukchi aboard the U.S. Revenue Cutter "Corwin" in late June 1881 and except for a short time in the Bering Sea, stayed until 14 September of the same year. His precise cruise course is not clear but he visited the Siberian coast as far west as North Cape including Herald and Wrangel Islands and the Alaskan coast as far east as Barrow. F. L. Jacques (1930) was in the Chukchi aboard the schooner "Morrissey" from 30 July to 25 August 1928 as part of the Stoll-McCracken Expedition. Most of the cruise track was south and east of Herald Island. His most easterly position was approximately 164° W and the most northerly, 73° N. Swartz (1967) published at-sea observations obtained by E. J. Willoughby aboard the research vessel "Brown Bear," from 6 August to 28 August 1960. Most of the cruise was south of Point Hope and in the Kotzebue Sound area; only seven legs were north of Cape Lisburne with 70° N being the most northerly position. Swartz's detailed account is the only one of the three that attempts to deal with observations on a quantitative basis. In addition to these accounts Stresemann (1949) discussed the birds observed and collected on Captain Cook's last voyage. The "Resolution" and "Discovery" were in the Chukchi from 11 August to 3 September 1778 and from 5 July to 31 July 1779. Cook sailed up both the Siberian and Alaskan coasts until he encountered ice. An expedition from Harvard University, aboard the power schooner "Polar Bear," sailed through the Chukchi Sea from Cape Serdze, Siberia to Cape Lisburne, and thence north to Point Barrow in July, 1913. Brooks (1915) and Dixon (1943) reported extensively on land observations in Siberia and on the north slope of Alaska before and after their Chukchi cross-

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ing, but they recorded few at-sea observations. Alverson, Wilimovsky, and Wilke (1960) made casual observations in August 1959 from Cape Lisburne to Kotzebue while engaged in fisheries research (Alverson and Wilimovsky 1966).

Much of the information on seabirds in the Chukchi Sea has been obtained by land-based observers and has been summarized by Bailey (1948) and Gabrielson and Lincoln (1959). Barrow has been the center of ornithological work in arctic Alaska. Harting (1871) collected in the area of Barrow and in Kotzebue Sound from 1852 to 1854. Murdoch (1885) collected at Barrow from 1881 to 1883 as part of the International Polar Expedition. McIlhenny (Stone, 1900) spent 1897 and 1898 doing extensive collecting at Barrow. In 1921 and 1922, A. M. Bailey and R. W. Hendee (Bailey, 1948) collected along the entire arctic coast of Alaska with the most intensive work being done in the area of Wainwright. From 1922 to 1945 Charles Brower (Bailey, 1948) collected at Barrow and greatly increased the number of species known for that area. Pitelka and his students have amassed a number of unpublished "opportunistic" records of seabirds for the Barrow area during studies of shorebird ecology. Their only publications on seabird species, however, are Pitelka, Tomich, and Treichel (1955a, 1955b), and Maher (1970). Ornithological records from the Barrow-Wainwright area southwest to Point Hope are few and scattered. Tarelton Bean (1382) collected along the Siberian and Alaskan shores of the Chukchi Sea in 1880 while F. S. Hersey (1916) visited both coasts in 1914. Benjamin Sharp visited points along the Alaskan coast in the summer of 1895, as did Seale (1898) in 1896. The Cape Thompson and Kotzebue Sound areas have been more intensively studied. Grinnell (1900) spent a year in Kotzebue Sound in 1897 and 1898 collecting birds. During the Project Chariot Program (Wilimovsky and Wolfe 1966) the birds of the Cape Thompson region were studied from 1959 to 1961 (Williamson, Thompson and Hines, 1966 and Swartz, 1966).

Studies of marine mammals in the Chukchi Sea area are likewise few. The whales, seals, walrus, and bears that are utilized for skins, oil, and food by the Eskimos move north with the edge of the pack ice in summer and are mainly hunted during migration in the fall and spring or from the ice in winter. Investigations, such as that of Johnson, Fiscus, Ostenson, and Barbour (1966) in the Chukchi Sea, during Project Chariot have depended largely on kills by native hunters and less on at-sea or aerial surveys. The major sources of general information on northern Alaskan marine mammals are Scammon (1874), Nelson and True (1887), Bailey and Hendee (1926), Rainer (1945), Brooks (1954), and Bee and Hall (1956).

CRUISE TRACK AND ENVIRONMENTAL CONDITIONS

The cruise track in the area of concentrated study between Icy Cape and Cape Lisburne was determined partly by ice conditions that the ship encountered. In general, the northern and western portions of the area were surveyed early in the cruise while the pack ice was less extensive; the inshore, southern portion was last to be sampled. The entire cruise track and all station coordinates can be found in the preface to this Oceanographic Report, while figures 1 and 2 present only stations and transects where bird watches were kept. Dates, hours, and positions for transects and stations are given in table I. No observations were made at night when the ship was sailing between stations. Station numbers, shown in squares on figure 1, are the same as those used for oceanographic, geological, and marine biological sampling in other phases of the study. Transects, with ship's direction indicated by an arrow, are designated by number on the midpoint. In this paper "the study area" denotes the zone of intensive investigation between Icy Cape and Cape Lisburne (stations 8–91 and transects 9–41), in which we operated, 25 September to 17 October. Observations were also made while the ship was anchored and in transit near Point Barrow 22–23 September (stations 1, 1′ and transects 1–3), in transit south to Icy Cape 23–24 September (stations 5–7 and transects 4–8), and in the Bering Strait en route to Nome 18 October (transect 42) (fig. 2).

The eastern Chukchi Sea is a shallow basin with depths of 10 to 30 fathoms and no prominent features on its gravel, sand and silt bottom. The main currents are from the south through the Bering Strait. Details of bottom

contours, sediments, currents, and seawater chemistry encountered during the cruise may be found in other sections of this Oceanographic Report (Ingham and Rutland; and Barnes).

Weather conditions were remarkably good for early fall in the area so that bird observations were possible on almost all days (table I). Daytime air temperatures ranged from 3.2° C to −8.6° C during the first week to —6.6° C to —16.6° C in the last week. Temperatures dropped about 4° C as the ship approached extensive areas of pack ice. Seas were moderately calm throughout the cruise, in part due to the proximity of pack ice. Winds were seldom greater than 25 knots. What little precipitation there was, fell mostly as snow at night. Days were generally overcast, but cloud cover was high and visibility was seldom less than 7 miles. Surface water temperature ranged from 4.0° C in ice free areas early in the cruise to −1.8° C later when ice began to form in the study area.

Seasonal change in hours of daylight is dramatic north of the Arctic Circle. At the equinox, 22–24 September, we experienced 12 hours 19 minutes of daylight. This decreased 8 to 9 minutes a day so that by the end of the cruise, 16–18 October, we had only 8 hours 50 minutes of daylight, a reduction of 25 percent.

Pack ice was present or nearby throughout the entire period that the ship was north of Cape Lisburne. The relatively abrupt edge of the arctic pack (shown in dotted lines in fig. 3) generally moves north and south with the prevailing wind. It closed in on the study area from the north during the course of the survey. Our observations of ice conditions, shown as oktas or eighths of total coverage on figure 3, should be compared with the cruise track (fig. 1 and table I).

Conditions near the Bering Strait were more moderate on 18 October. Air temperature varied from —0.8° C to —1.7° C, wind and waves were calm to moderate. Occasionally, the sun appeared through the high clouds and visibility was excellent. Sea surface temperature ranged from 1.2° C to 2.4° C.

Stomach contents from specimens prepared aboard ship were preserved at once in formalin while the remainder of the stomachs were removed later and preserved in 70 percent alcohol and glycerine. Food items were identified by Divoky with assistance from Mr. Bruce L. Wing and Dr. Jay C. Quast (National Marine Fisheries Service). Ectoparasites were collected aboard ship and Mallophaga were later identified by Dr. K. C. Emerson, research associate, Department of Entomology, Smithsonian Institution, where the specimens are deposited.

Midwater and benthic invertebrate faunal samples collected during the cruise were abundant in species and individuals (Wing, elsewhere in this Oceanographic Report); but fish, especially large individuals, were strangely rare. The area may, however, be an important "nursery" for young Arctic Cod *(Boreogadus saida)* (Quast, personal communication).

METHODS

During daylight hours we maintained a watch for birds and marine mammals from the flying bridge of the GLACIER (48 feet above waterline) whenever the ship was underway. Occasionally weather conditions forced us to retreat to the pilothouse (39 feet above waterline) or the crow's nest (74 feet above waterline). Visibility was good in all directions, except astern from the pilothouse. Species, numbers, time, and behavior and appearance notes were recorded on sealog sheets at the time of observation. Tracks, positions, and ice conditions relative to the ship were plotted later from bridge navigation data while weather conditions, sea state, and water temperature were recorded every 3 hours by the ship's marine science technicians. General ice condition reports were received on board ship from the U.S. Navy station at Kodiak, Alaska, based on air reconnaissance. On station we recorded the presence and abundance of birds and caught a few specimens on fishlines. Whenever weather conditions, presence of birds, and operability of small boats permitted, we went over the side to collect birds for chemical analysis, food habit studies, parasites and museum specimens. Most of the 66 specimens collected were frozen for later preparation either as whole pickles or as skeletons, but a few were prepared as spread-wing or study skins aboard ship (table II).

Frozen whole specimens of birds were turned

over to Drs. Lucille F. Stickel and Eugene H. Dustman at the Patuxent Wildlife Research Center, Laurel, Maryland, where tissue samples of muscles and organs were removed for pesticide and heavy metal analysis. The results of the analyses for chlorinated hydrocarbons, polychlorinated biphenyls, and heavy metals, especially mercury, will be reported elsewhere when complete. Carcasses were returned to the Smithsonian Institution for museum specimens.

Marine science technicians aboard the GLACIER recorded bird observations sporadically and collected three specimens from 18 August to 21 September while the ship was engaged in geological sampling in the Chukchi Sea or en route to Barrow. Where their observations augment ours they have been included in the species accounts.

Sightings were plotted by species on maps (figs. 4 to 40) with all mammals and birds, except gulls, seen during 20-minute intervals, or fractions thereof, being summed. Abundance is indicated by symbols keyed in powers of three (see figs. 4 and 5 for key). Gulls, which were attracted to the ship and tended to congregate in the wake, were counted at least once in each 20-minute interval and at stations. The highest count was entered in the log and later mapped.

SPECIES ACCOUNTS

The sequence of species and nomenclature in the following accounts follows the American Ornithologists' Union Check List (1957) for birds and Rice and Scheffer (1968) for mammals. General information on distribution, migration and food habits in Alaska is based on Bailey (1948) and Gabrielson and Lincoln (1959) for birds and Bee and Hall (1956) and King (1964) for mammals unless otherwise stated.

The following terms, used to categorize feeding methods of seabirds in the species accounts, are based on Ashmole and Ashmole (1967).

- Contact dipping—The bird remains airborne and forward motion does not stop as it snatches its prey out of the water.
- Hovering—Forward motion ceases as the bird with wings beating picks its prey from either water or ice surface.
- Plunge to surface—The bird partly folds its wings and drops to the water surface but does not fully enter the water. No species were observed plunging deeply in pursuit of prey.
- Surface feeding—The bird swims on the surface and picks up its prey on or just below the surface.
- Surface diving—The bird dives while swimming on the surface and pursues its prey under the water.

Loons (*Gavia* spp.)

The Yellow-billed (*Gavia adamsi*), Arctic (*G. arctica*), and Red-throated Loons (*G. stellata*) breed on the arctic coast of Alaska, while the Common Loon (*G. immer*) breeds only as far north as Kotzebue Sound. All four species winter from the Aleutians and southern Alaska southward. Bailey (1948) found that most of the loon migration at Wainwright took place in early and mid-September. Of the 112 loons we observed (fig. 4), one seen between Wainwright and Barrow on 24 September was identified as *G. adamsi*. The Common Loon was seen twice: one north of the usual breeding grounds 20 miles northwest of Point Lay on 4 October and another in the Bering Strait on 18 October (fig. 12). The remainder of the loons consisted of *G. arctica and G. stellata*. The similarity of the two species in winter plumage and the distance from which most birds were observed did not allow positive identification, but on the basis of flight characteristics we thought the majority were Arctic Loons.

Loons were common in the area of Barrow and along the coast to the study area (fig. 4). In the study area, we observed loons primarily within 40 miles of land. The majority was headed southwest. The largest number (54 in 3½ hours) was seen on transects 10 and 11 extending northwest from Point Lay 27 September. No loons were observed in the study area after 6 October. Loons feed on fish obtained by surface diving.

Northern Fulmar (*Fulmarus glacialis*)

The Northern Fulmar breeds north to St. Lawrence Island in the Bering Sea, and birds observed in the Chukchi Sea in the summer are probably all nonbreeders. It winters from the Aleutians southward. Nelson (1883) observed it in the area of Herald and Wrangel Islands and believed it might nest there but subsequent

investigations have failed to show evidence of breeding. Summer observers have all recorded this species in the Chukchi. Nelson (1883) found it north to the pack ice. Jacques (1930) saw it occasionally south of 71° N and abundantly south of 68°30′ N in late August. Both Swartz (1967) and Alverson, Wilimovsky and Wilke (1960) found it to be uncommon in the southeast Chukchi in August. Fulmars were observed in early September by marine science technicians aboard the GLACIER. Their most northerly sighting was made at 72°22′ N, 167°22′ W on 6 September. The species was last observed on 17 September at 71°27′ N, 167°15′ W. We did not observe it in the Chukchi at all, but it was present in the Bering Strait throughout the day of 18 October (fig. 5). Most sightings were of less than five individuals; and all observations were of light phase birds. Jacques (1930) is the only observer to have seen dark phase birds in the Chukchi. They constituted roughly 1 percent of all the fulmars he observed. In the Pacific, dark phase individuals predominate in the southern portion of the breeding range and do not breed north of the Pribilofs. The fulmar is primarily a scavenger and obtains its food by surface feeding.

Slender-billed Shearwater *(Puffinus tenuirostris)*

The Slender-billed Shearwater breeds on islands in the southwest Pacific Ocean from September to May and migrates to the northern hemisphere from June to October. It is abundant in the Bering Sea in the summer and fall, and smaller numbers are found in the Chukchi Sea from July to November. Observations from this area in the fall are probably of nonbreeding individuals. Nelson (1883) "several times" saw birds he believed to be this species. Jacques (1930) found it extremely abundant in the western Chukchi in late August. Swartz (1967) reported it most frequent in the Point Hope and Cape Thompson area, with one of the sightings a flock of 500 to 1,000 individuals. Alverson, Wilimovsky, and Wilke (1960) observed it in increasing numbers in the month of August and groups of 200 to 300 were seen at the end of the month.

Marine science technicians aboard the GLACIER observed Slender-billed Shearwaters in the Chukchi in early and mid-September. Their most northerly sighting was made on 17 September at 71°27′ N, 167°35′ W, and their last sighting on 20 September at 68°22′ N, 167°54′ W. We only saw it south of 67° N in the Bering Strait on 18 October when it was observed on 12 of the thirty 20-minute intervals (fig. 6). Nine of these observations were of less than five individuals though flocks of up to 100 birds were observed on two occasions, east of East Cape and west of Cape Prince of Wales. Our lack of sightings in the study area indicates that most Slender-billed Shearwaters had left that area by late September. It occasionally stays later; Brower observed thousands at Barrow in September and October associated with the ice (Bailey 1948). The species feeds on the surface or, less commonly, dives for euphasid crustaceans, pelagic fish, and cephalopods.

Pelagic Cormorant *(Phalacrocorax pelagicus)*

The Pelagic Cormorant breeds commonly south of the Bering Strait but it is found only sparingly in the Chukchi Sea and probably does not nest north of the Cape Lisburne cliffs. When the Cape Thompson cliffs were censused in 1961 they were found to support 23 pairs (Swartz, 1966). Like other cormorants it is rare out of sight of land and has been observed only infrequently by pelagic observers. Nelson (1883) saw two birds in the area of Herald and Wrangel Islands. Jacques (1930) did not encounter it north of the Bering Strait. Swartz (1967) reported four observations, all near nesting cliffs. There are five records for Barrow in the spring, summer and fall and a January record for Wainwright (Bailey, 1948). We saw the species only once on 18 October when two birds were observed flying approximately 15 miles south of Cape Prince of Wales (fig. 12). Cormorants feed by diving for fish.

Oldsquaw *(Clangula hyemalis)*

The Oldsquaw is circumpolar north of 50° N in its breeding distribution and nests abundantly on both sides of the Chukchi Sea It is rarely observed far from land during the summer. It winters generally well south of the breeding range, but individuals have been observed at Barrow in early December. The only fall migration data for the arctic coast are those of Bailey (1948) who saw large flocks

off Icy Cape on 7 September and 1 October. The latest date he recorded them was 19 October.

The species was observed throughout the cruise (fig. 7). The larger flocks were all observed close to shore with the majority in the area of Point Lay where 2,400 were seen in a 3-hour transect on 25 September and smaller numbers on 4 October. Presumably some of the unidentified ducks seen at a distance in the study area were Oldsquaws (fig. 11). We observed a flock of 24 Oldsquaws off Cape Sabine on 16 October when new ice covered 7/8 of the water's surface. It appears that a few individuals remain in the Chukchi Sea until driven out by the formation of new ice. Small numbers were observed in the northern part of the Bering Strait on 18 October (fig. 9). Molluscs and crustaceans obtained by surface diving are the primary food items. The stomach of the single immature specimen collected at Point Lay 26 September (table II) contained only grit (table V).

Eiders *(Somateria spp. Lampronetta fischeri)*

Three species of eider were observed. Positive identification was possible only of the few males observed and of females that came near the ship. The Common Eider *(Somateria mollissima)* breeds commonly along the entire arctic coast. In September individuals gather to the east of Barrow and then fly west along the shore. Most of the Alaskan breeding records for the King Eider *(S. spectabilis)* come from the area of Barrow. As with all eiders the males migrate south before the females and young. Large flocks of males pass Barrow from late June until early August. Females and young migrate from late August through September. The main breeding grounds of the Spectacled Eider *(Lampronetta fischeri)* in northern Alaska lie to the east of Barrow.

Of the approximately 1,300 eiders seen in the study area only 100 or 7.7 percent were males. Four of the males were identified as King Eiders and the remainder were either Common or Spectacled. Only a single eider was seen in the area of Barrow and only one flock of six was seen from Barrow to the study area (fig. 8). The greatest numbers were observed on 25 September when large flocks were observed inshore in the area of Point Lay. Smaller flocks were observed in the same area on 4 October. Eiders were seen throughout the study area and small numbers were observed far from land. Some of the "unidentified ducks" seen at a distance in the study area were eiders (fig. 11). One was observed in a lead during the deepest penetration into heavy pack ice while small flocks were also found off Cape Sabine when new ice covered 7/8 of the water's surface. Eiders were seen in the northern part of the Bering Strait on 18 October (fig. 10).

Eiders feed by surface diving for benthic molluscs and crustaceans. The stomach of one of the two immature specimens of Common Eider collected (table II) contained remnants of gastropods and plant material (table V); the other was empty.

Common Scoter *(Oidemia nigra)*

The Common Scoter is circumpolar north of 45° N in its breeding distribution but is uncommon on the arctic coast of Alaska. We observed it on two occasions: a flock of 300 individuals on 24 September near Wainwright, and a flock of 25 west of Point Lay on 27 September (fig. 14).

Red-breasted Merganser *(Mergus serrator)*

The Red-breasted Merganser is a rare breeder on the arctic coast of Alaska but is common south of Kotzebue Sound. It was seen only twice in the study area: one individual at Point Lay on 26 September and another on 27 September, at sea 20 miles west of Point Lay (fig. 14). At Nome on 19 October a single bird was observed in the small boat harbor swallowing a fish.

Red Phalarope *(Phalaropus fulicarius)*

The Red Phalarope is circumpolar north of 50° N in its breeding distribution and is found in abundance on both the Siberian and Alaskan sides of the Chukchi Sea. This peculiar shorebird winters in pelagic environments in the southern hemisphere. Fall migration begins as early as July. Summer observers have found it common throughout the Chukchi. Both Nelson (1883) and Jacques (1930) encountered large concentrations at the edge of the ice. Swartz (1967) mentioned 59 sightings of phalaropes with no areas of large concentration. From the abundance of summer pelagic observations in

the Chukchi it appears that individuals disperse to the open ocean after breeding rather than immediately migrating southward along the coast. Coastal concentrations may occur at times, however, as Bailey (1948) found 100 in the shallows at Wainwright during the first week in September.

Eleven sightings of phalaropes were made between Point Barrow and Icy Cape and nine other sightings in the study area. Most of the observations were of flocks of 10 or fewer individuals (fig. 13). All were identified as *P. fulicarius* although it is possible some were the Northern Phalarope *(Lobipes lobatus)*, a species less abundant at sea but frequent in Alaskan coastal waters. Our few sightings indicate that most individuals had left the Arctic by late September. We last observed it in the study area on 7 October but it has been recorded at Barrow as late as 16 October (Murdoch, 1885). Our sightings were too few to demonstrate an ice affinity that other observers have commented on, but the largest flocks were close to the pack ice in the area of Barrow and Wainwright. A single bird was also observed on 18 October in the Bering Strait (fig. 12). Phalaropes feed on crustaceans and small fish on the surface.

South Polar Skua *(Catharacta maccormicki)*

A large, all dark bird with a conspicuous white flash at the base of the primaries passed about 20 feet directly overhead while we were in one of the ship's small boats at 70°18′ N, 164°41′ W, on 29 September (fig. 14). It was about the same size as nearby Glaucous Gulls, but had broader more rounded wings. Its dark greyish brown breast and uniformly dark back lead Watson (who was familiar with skuas in the North Atlantic and Antarctic) to conclude that it was a dark phase South Polar Skua from the Antarctic rather than a Northern Skua *(C. skua)* from the Atlantic. This is the first record of any skua in arctic Alaska although a specimen of South Polar Skua has been collected and another seen near the Aleutians (Max Thompson, personal communication and Sanger in Gibson, 1970). Three Ross' Gulls harried the skua as it flew away.

Jaegers *(Stercorarius spp.)*

All three species of jaeger, the Pomarine *(Stercorarius pomarinus)*, the Parasitic *(S. parasiticus)*, and the Long-tailed *(S. longicaudus)*, are circumpolar north of 55° N in their breeding distribution and are found in arctic Alaska. They winter in temperate and tropical seas, beginning southward migration as early as mid-July.

The Pomarine has the most restricted breeding range in Alaska with most records coming from the Barrow area where Brower considered it to be more coastal than the other two species (Bailey, 1948). Outside of the breeding season, jaegers obtain much of their food by robbing other birds so that their distribution at sea and during migration is somewhat dependent on the presence of other species. Nelson (1883) observed the Pomarine Jaeger in scattered areas close to shore in the Chukchi. He found it more common on the Siberian side than the Alaskan side except at Barrow where it was abundant. Jacques (1930) considered it at times to be the most abundant bird in the western Chukchi. Swartz (1967) reported seven sightings all north of 67° N.

We observed Pomarine Jaegers on six occasions, totaling 11 individuals (fig. 15). In early September observers aboard the GLACIER saw jaegers more frequently, and our observations are of the last of the fall migration. None was observed in the study area after 29 September, but a single individual was sighted in the Bering Strait on 18 October (fig. 12). Most of our sightings were in ice areas where large concentrations of other birds were present. One case of harrassment of gulls was recorded, two Pomarine Jaegers chasing an Ivory Gull. Five of the seven Pomarine Jaegers closely observed were dark phase.

We observed a single Parasitic Jaeger on 30 September (fig. 14). This is the least abundant jaeger in the Barrow area (Bailey, 1948). Both Nelson (1883) and Swartz (1967) reported this species from the Chukchi. Swartz's 12 observations were all north of 67° N. No Long-tailed Jaegers were encountered. Summer observers in the Chukchi have found it uncommon. We saw an unidentified jaeger on land at Barrow on 22 September.

Glaucous Gull *(Larus hyperboreus)*

The Glaucous Gull is a common to abundant breeder on both sides of the Chukchi Sea and at Herald and Wrangel Islands. Its scavenging

and predatory habits cause breeding individuals to concentrate at seabird cliffs; 150 pairs bred at Cape Thompson in 1961 (Swartz, 1966). During the breeding season it remains near land and is not commonly seen far out at sea. Nelson (1883) mentions no pelagic observations; Jacques (1930) found it present but uncommon north to Herald Island. Most observations reported by Swartz (1967) were within 25 miles of land. There are little fall migration data for the arctic coast. Birds which breed inland move to the coast where both adults and young stay until driven south by ice and lack of food. Bailey (1948) observed hundreds passing Wainwright on 16 September. The latest date he recorded the species was 19 October.

Glaucous Gulls were observed throughout the cruise (fig. 16). They were abundant at Barrow on 23 September when a flock of 40 individuals followed the ship while it was just south of the pack ice. From Barrow to the study area only small infrequent flocks were seen. They were present throughout the study area but were most common in the northeast portion and at other stations close to the shore. They were present throughout the day in the Bering Strait (fig. 21). The species displayed no obvious affinity for ice areas. Approximately 25 percent of all birds seen were immatures (fig. 17).

Glaucous Gulls tended to flock less than other gulls and single individuals were frequently seen on transects. On the other hand, large numbers gathered about the ship on stations to accept scraps thrown over the side (table III). Most of its food is probably live fish and crustaceans but we also saw it feeding on Walrus dung. Hovering, contact dipping and surface feeding were all observed for this species (fig. 17). Examination of stomach contents indicates that fish may be the major food during this time of year (table V). One individual had eaten ascidians including a pyrid, *Halocynthia* sp. or *Bottenia* sp. and one each of the styelids *Polenaia corrugata* and *Cnemidocarpa* sp. (the latter identifications are tentative). Three of the seven specimens collected were adults (table II).

Slaty-backed Gull *(Larus schistisagus)*

On 25 September approximately 20 miles northwest of Point Lay, a large dark-backed gull was observed that was most probably a Slaty-backed Gull *(Larus schistisagus)* (fig. 14). This is a species of the Siberian Pacific coast and is rarely found in Alaskan waters. A specimen collected by Bailey at Icy Cape on 16 September 1921 was thought to be this species, but according to Bailey (1947) further investigation proved it to be the Siberian Lesser Black-backed *(Larus fuscus)*. A straggler has also been reported for Herald Island (Nelson, 1883).

Herring Gull, *(Larus argentatus)*

The Herring Gull is found throughout most of the northern hemisphere including the east Canadian Arctic and Siberia but does not breed on the arctic coast of Alaska. In the fall, and probably in the spring, it is a regular but uncommon migrant in northern Alaska. The majority of Alaskan migrants are "Thayer's Gull," *L. a. thayeri* which breeds in arctic Canada and winters along the Pacific coast of North America. We observed this species five times in the study area (fig. 18). Three of the six individuals seen were immatures. Two other sightings were made in the Bering Strait; a single individual at 66°22′ N, and a flock of five at 66°05′ N.

This species is an unspecialized feeder similar to *L. hyperboreus*. The stomach of the second-year bird collected (table II) contained remnants of Arctic Cod (table V).

Ivory Gull *(Pagophila eburnea)*

The Ivory Gull, a high arctic species reported as far north as 86° N (Dementiev and Gladkov 1961), breeds north of 70° N. The known breeding grounds closest to the study area are at Herald Island and in the Canadian Archipelago. Outside the breeding season, it frequents the pack ice, and the southern extent of its wintering range is largely determined by the southern margin of the pack ice. Ivory Gulls move through the Chukchi Sea with the ice in the spring and fall. Small numbers are probably present in the open leads throughout the winter. The pelagic habits of this species have caused land observers to underestimate its abundance in the Chukchi (see, for instance, Gabrielson and Lincoln 1959). It was reported common in the "frozen" Chukchi Sea on Cook's last voyage from August to September 1778 and in July 1779 (Stresemann, 1949). It is not

clear how far north Cook sailed, but no other summer observers have encountered Ivory Gulls at sea although all have come in contact with the pack ice. Both Nelson (1883) and Jacques (1930) observed breeding birds at Herald Island.

We observed few Ivory Gulls in the Barrow area although they were common near Wainwright (fig. 19). In the study area this species was largely associated with the ice (table IV, fig. 20). Large flocks assembled at stations with smaller groups being observed on transects (table III). The marine science technicians saw a pair of what they tentatively identified as this species at 71°25′ N, 167°13′ W on 17 September when ice surrounded the ship. None was observed south of the study area. Immatures constituted roughly one quarter of all individuals observed.

Outside the breeding season, the Ivory Gull is thought to be primarily a scavenger feeding to a great extent on the kills of Polar Bears. The only scavenging we saw, other than some feeding on the ship's garbage, were small flocks observed over whales on two occasions and a single individual feeding on Walrus dung on the ice. The primary methods of obtaining food we observed were hovering and contact dipping near ice cakes. Fish appear to be the primary food obtained in this way since Arctic Cod constituted the bulk of the food items found in stomachs (table V). One individual had eaten a pyrid ascidian, either *Halocynthia* sp. or *Bottenia* sp. Six of the 14 specimens collected were immatures (table II). Mallophaga from this species were identified as *Saemundssonia lari* (O. Fabricius 1780).

Black-legged Kittiwake *(Rissa tridactyla)*

The Black-legged Kittiwake breeds throughout the Chukchi Sea wherever suitable nesting cliffs exist, almost as far north as Barrow. It was the third most abundant species at the Cape Thompson cliffs in 1960 with 13,000 breeding pairs (Swartz, 1966). This most pelagic of all gulls feeds far out to sea in all seasons. Summer observers have found it common in the Chukchi. Nelson (1883) saw it in all parts of the arctic with large numbers present at Herald Island and smaller numbers at Wrangel Island. Jacques (1930) found it sometimes abundant throughout the Arctic. Swartz (1967) reported it most common near the breeding cliffs in the Point Hope-Cape Thompson area. The species probably winters at sea from the Aleutians southward but there is no evidence of mass migration.

Kittiwakes were present in small numbers in the area of Barrow and along the coast to the study area. In the study area it was the least common of the major species of gulls we observed (fig. 23) and tended to flock less than the others (table III). It showed affinity for areas of open water (table IV) and in the Bering Strait it was seen throughout the day 18 October (fig. 22). Approximately three quarters of all individuals observed throughout the cruise were immatures.

Plunging to the surface was the most common mode of feeding observed for this species. On the few occasions when it was observed in ice areas, individuals were seen feeding while hovering near ice cakes. The stomachs of the four specimens collected (table II) contained remnants of Arctic Cod (table V). Mallophaga from this species were identified as *Saemundssonia lari* (O. Fabricius 1780).

Ross' Gull *(Rhodostethia rosea)*

The breeding grounds of Ross' Gull are restricted to the Kolyma and Indigirka River deltas (62 27′ to 70°30′ N, 142° to 162° E) in northern Siberia. There are scattered records of pairs of birds elsewhere in the arctic during the spring and summer but only one definite breeding record outside of northern Siberia, a nest found on Disko Bay in western Greenland (Dalgleish, 1886). Two pairs were taken by Brower near the Seahorse Islands southwest of Barrow on 16 June 1935. All four were in breeding plumage though none had bare brood patches. There are also records of single birds taken in the summer on the arctic coast (Bailey, 1948). Jacques (1930) is the only summer observer to encounter this species in the Chukchi. He saw a total of eight birds in mid and late August; all were north of 70° N near Herald and Wrangel Islands. In the fall, Ross' Gulls migrate east through the Chukchi Sea but there are few records for the Bering Sea. They are commonly observed at Barrow in September and October, and on the basis of these observations the wintering grounds are thought to lie to the east of Barrow. They

probably are pelagic in the high arctic when not breeding and have been found at extremely high latitudes. The "Fram" expedition encountered them between 84°27′ and 84°41′ N in July and August (Collett and Nansen, 1900).

The species was present in the area of Barrow and along the coast to the study area, but large flocks were observed only in the study area (fig. 24). It was most common in the northeast portion of the study area where the ice coverage was greatest. This was the most social of the gulls we observed and only 10 percent of the seventy 20-minute interval counts were of single individuals (table III). Flocks of approximately 120 birds were observed on two occasions southwest of Icy Cape and at one of the most westerly stations northwest of Cape Lisburne (fig. 25). Approximately one-half of all birds seen were immatures (fig. 26). Ross' Gull was absent from the Bering Strait on 18 October.

Some or all of the birds recorded by the marine science technicians on the GLACIER as Bonaparte's Gulls, *Larus philadelphia*, or Arctic Terns, *Sterna paradisaea*, that were "following the ship" were most probably Ross' Gulls. Bonaparte's Gull breeds north to Kotzebue Sound but has not been reported farther north. The Arctic Tern breeds along the arctic coast, but most leave Alaska on migration toward southern hemisphere winter grounds by early September. Sightings of this nature occurred on 8, 17, 18, 19, and 20 September between 68°35′ and 71°13′ N, 164°13′ and 167°43′ W.

We observed three different methods of feeding by this species. Like other gulls, individuals fed by hovering in the area of ice cakes while in more open water they plunged to the surface. Flocks sitting in leads in the ice were feeding on the surface. One instance of an individual hovering while feeding on Walrus dung was observed. Arctic Cod and crustaceans appear to be of about equal importance as food items (table V). Three stomachs were examined in detail. The amphipod *Apherusa glacialis* was the commonest crustacean found in the stomachs examined, with as many as 80 in one individual. Also present but in lesser numbers were the large amphipods *Atylus bruggeni*, *Anonyx nugax* and *Gammarus locusta*. One stomach contained portions of the exoskelton of a beetle. Insects are the chief food during the breeding season (Buturlin, 1906). Mallophaga collected included both *Saemundssonia lari* (O. Fabricius 1780) and *Quadraceps eugrammicus brykı* (Timmermann 1952).

Sabine's Gull *(Xema sabini)*

Sabine's Gull is circumpolar between 65° N and 80° N in its breeding distribution and breeds locally on the arctic coast of Alaska. In summer, when there are few at-sea records, it obtains most of its insect food by contact dipping in tundra ponds while, after breeding, it feeds on invertebrates cast up on the shore and fish that it captures by contact dipping. Nelson (1883) did not observe it in the Chukchi. Jacques (1930) saw adults on 6 days during August and juveniles on 23 and 25 August south of Wrangel Island. Swartz (1967) reported six scattered observations in the eastern Chukchi.

The species winters in the southern hemisphere, but there are surprisingly few records of migrating birds for Alaska, although large numbers of migrants are seen in fall off the Oregon coast. This lead Gabrielson and Lincoln (1959) to suggest that it stayed well offshore while moving. Birds have been observed as late as mid-September at Wainwright and 22 October at Barrow, but the bulk of migration probably takes place earlier.

We observed Sabine's Gull only in the area of Barrow and Wainwright on September 23 and 24 (fig. 27). Eight flocks were observed near ice cakes with the largest flock containing 10 individuals. Our few observations suggest that most individuals had already migrated south and the lack of subsequent observations indicates that migration, in this area at least, takes place close inshore, contrary to Gabrielson and Lincoln's conclusion.

Murres (*Uria* spp.)

Two species of murres are found breeding in the Chukchi Sea. The Thick-billed Murre *(Uria lomvia)* is more northern in its distribution than the Common Murre *(U. aalge)*. Both species breed in the Bering Strait and at Cape Thompson, while *U. lomvia* also nests at Herald and Wrangel Islands, in small numbers near Barrow and probably somewhere east of Barrow. Murres are the most abundant birds at

Cape Thompson. In 1960, 118,000 pairs of Thick-billed and 78,500 pairs of Common Murres were breeding on the cliffs. Summer observers have found them primarily in the waters around breeding cliffs. Swartz (1967) reported that during the breeding season *U. lomvia* constituted 90 percent of all murres seen further than 5 miles from shore. Since 60 percent of the murres breeding on the cliffs are *U. lomvia*, he believed that *U. aalge* fed closer to shore at least during the breeding season. He reported few murres feeding more than 40 miles from the cliffs. The Thick-billed Murre winters in open water at the edge of the pack ice and moves north and south with the ice margin. There is thus no well-defined migration, and birds have been recorded as far north as Barrow in December.

We made scattered sightings of single birds in the eastern section of the study area, but only on the most westerly transects were murres observed in numbers (fig. 29). They could not be identified to species, however, and the similarity of murres and the Horned Puffin at a distance caused us to list some birds as large black and white alcids (fig. 30). Murres were seen throughout the day on 18 October in the Bering Strait (fig. 28). Murres feed by diving for fish and crustaceans. The stomach of the one Common Murre collected (table II) contained remains of Arctic Cod and a single larval hermit crab *(Pagurus spp.)* (table V).

Guillemots *(Cepphus spp.)*

Both Black *(Cepphus grylle)* and Pigeon Guillemots *(C. columba)* breed in the Chukchi Sea. The Black Guillemot is also found in the North Atlantic and Arctic Oceans, but the Pigeon is restricted to the Pacific sector. The Chukchi is the only area where the two species are sympatric, with both breeding on Herald and Wrangel Islands and at Cape Thompson. The Pigeon Guillemot also nests in the Bering Strait area while the Black Guillemot is suspected to nest near the Seahorse Islands (Bailey, 1948). Black Guillemots have recently taken advantage of artificial "burrows" provided by discarded oil drums and have nested at the tip of Point Barrow (MacLean and Verbeek 1968). Swartz (1966) found fewer than eight pairs of either species breeding at Cape Thompson but guillemots rarely breed anywhere in dense concentrations. They are found primarily in the littoral zone during the breeding season and are generally found in pelagic situations only at the edge of the pack ice in the nonbreeding season.

Some Black guillemots probably remain in the Chukchi all winter, for specimens have been taken in almost every month in arctic Alaska and they are present whenever there is open water at the ice edge. Bailey (1948) suggests they may even live in pressure ridges under the ice.

Summer observers in the Chukchi give conflicting reports on the status of these two sibling species that are not easy to separate even in the breeding season. Nelson (1883) observed both species and considered the Pigeon Guillemot to be the more common of the two. He found it to be the most abundant bird at Herald Island where, however, he also observed numerous Black Guillemots. Jacques (1930) did not observe the Pigeon Guillemot north of the Diomedes but found the Black Guillemot common north of 69° N. He found it to be especially abundant at Herald Island and at the edge of the ice. In the eastern Chukchi, Swartz (1967) reported only the Pigeon Guillemot. One of two sightings was off Cape Lisburne and the other at the edge of the pack ice at 70°50′ N, 165°30′W.

All guillemots we observed were in winter dress and were identified as *C. grylle* (figs. 26 and 32). The only possible sighting of *C. columba* was an immature individual west of Cape Lisburne. Although it was not common at Barrow, a flock of 30 individuals was observed in that area. Lesser numbers were seen on transects 4–8 from Barrow to the study area. In the study area, the great majority of observations were on the most northerly transects near the edge of the pack ice with the largest concentrations in the eastern portion of the study area. None was seen in the Bering Strait.

Fish are the primary food of guillemots, but crustaceans sometimes also constitute a large portion of the diet. The stomachs of the three Black Guillemot specimens collected (one adult, two immature; table II) all contained remnants of Arctic Cod (table V). One also contained four crustaceans: two *Gammaracanthus lor-*

icatus, *Gammarus locusta* and *Weyprechtia pingius*.

Kittlitz's Murrelet *(Brachyramphus brevirostre)*

Kittlitz's Murrelet breeds in scattered coastal locations in Alaska from Leconte Bay possibly north to Point Barrow and on the Chuckost Peninsula in Siberia but is rare north of the Bering Strait. Breeding of this inconspicuous species probably has been overlooked by investigators. Brower took many specimens at Barrow from August to October but, although Bailey (1948) believed suitable nesting sites existed between the Seahorse Islands and Barrow, there is still no proof of nesting. The only previous pelagic observations are those reported by Swartz (1967): three sightings, totalling four birds, north of Cape Lisburne. Little is known of the migration of the species. There are no winter records, and the latest specific fall record for Barrow, is one collected by Brower 4 October 1927 (Field Museum specimen).

We recorded 15 sightings of Kittlitz's Murrelet between 24 September and 8 October, eight of them between Barrow and Icy Cape (fig. 33). The remainder was in the northern part of the study area. It was never abundant, with 12 of the sightings being of three or less individuals. Small numbers were also seen in the southern part of the Bering Strait on 18 October (fig. 34). These observations probably are now the latest on record for Kittlitz's Murrelet in Alaska. Little is known about the food habits of this species though invertebrates probably constitute most, if not all, of its food.

Parakeet Auklet *(Cyclorrhynchus psittacula)*

The Parakeet Auklet breeds near the Bering Strait and the Aleutian Islands. Small nesting colonies occur on the Siberian coast in the western Chukchi Sea (Koslova, 1961) but none on the Alaska Chukchi coast. Jacques (1930) saw several flocks of small auklets at 69°40′ N, 170°00′ W on 14 August which may have included this species. Grinnell (1900) found it common in Kotzebue Sound on 1 June but Swartz (1967) reported only one sighting of several individuals there in August. There are only three records for Barrow: 12 September 1896 (Seale, 1898), 3 October 1932, and 27 July 1942 (Bailey, 1948). The species winters in variable numbers off the Pacific coasts of Canada and the United States, but little is known of its migration.

We observed three individuals in the study area at 69°47′ N, 167°50′ W on 9 October (fig. 14). A single bird was seen in the Bering Strait on 18 October (fig. 12).

The Parakeet Auklet feeds by diving for planktonic amphipods, arrow worms, fish larvae, polychaetes, and cephalopods (Bedard, 1969).

Crested Auklet *(Aethia cristatella)*

The Crested Auklet has the same breeding range as the Parakeet Auklet; it is one of the most abundant species breeding on the Diomedes but is not known to breed in Alaska north of the Bering Strait. Bailey (1948) listed a number of summer records for Barrow and believed a few individuals might nest on arctic coastal boulder fields. Nelson (1883) observed a small number at Herald and Wrangel Islands. Jacques' (1930) only possible sighting was of unspecified auklets at 69°40′ N, 170°00′ W 14 August. Swartz (1967) had two sightings 18 miles west of Cape Thompson. The Crested Auklet winters in ice-free waters from the Bering Strait southward, especially near the Pribilofs, Aleutians, and Kodiak.

Seven of our 12 sightings were northeast of the study area between Barrow and Icy Cape (fig. 36). The largest concentration was a group of more than 100 individuals swimming among ice cakes suggesting a considerable northward movement after breeding. This is the only alcid in which a large flock (30 individuals) was observed sitting on the ice. None was observed after 27 September.

No specimens were collected. Studies during the breeding season have found herbivorous zooplankton *(Calanus* and *Thysanoessa)* to be the primary food (Bedard, 1969).

Horned Puffin *(Fratercula corniculata)*

The Horned Puffin is a north Pacific species found breeding in the Chukchi Sea from the Bering Strait north to Cape Lisburne. Nelson (1883) and Jacques (1930) reported it from Herald Island but there are no definite breeding records. Swartz (1966) found 950 pairs breeding at the Cape Thompson cliffs in 1960. Summer observers have reported Horned

Puffins primarily from Point Hope and Kotzebue Sound. Swartz (1967) thought they probably utilized the same feeding areas as murres. They winter in ice-free waters in and somewhat south of the breeding grounds.

We identified Horned Puffins only on the most westerly transects in the study area (fig. 31). They appeared to outnumber murres though the difficulty in separating murres and Horned Puffins at a distance did not allow accurate estimation of relative numbers (see also fig. 30). One was seen in the Bering Strait (fig. 12).

Small fish constitute the bulk of the diet of this diving species although it probably also takes some crustaceans.

Snowy Owl *(Nyctea scandiaca)*

While passing through the Bering Strait within sight of both Alaska and Siberian coasts on 18 October we observed Snowy Owls nine times in about four hours (fig. 35). Though only one bird was observed at a given time, differences in plumage and direction of flight indicated that at least four individuals were involved. Glaucous Gulls and Kittiwakes drove the owls away from the ship; otherwise, they might have landed in the rigging. Snowy Owls are resident in arctic Alaska but in years of lemming scarcity they may irrupt southwards.

Raven *(Corvus corax)*

On 17 October, 10 miles west of Cape Lisburne, a Raven flew over the ship (fig. 14). This species is a year-round resident throughout arctic Alaska.

Yellow Wagtail *(Motacilla flava)*

A Yellow Wagtail in winter dress landed on the deck of the ship in the Bering Strait 20 miles east of East Cape on 18 October and remained aboard for about 5 minutes (fig. 14). The Yellow Wagtail is an Old World species that has become established in western and northern Alaska. Individuals migrate across the Bering Strait in the spring and fall and four previous pelagic observations have been reported for this region. On Cook's last voyage one was reported in the Bering Strait at 66°00′ N on 3 September 1778 (Stresemann, 1949). Swartz (1967) reported three observations for the Chukchi Sea: one off Point Lay on 7 August and two southwest of Point Hope on 10 and 13 August. Our sighting is an extremely late date for this area; most individuals leave Alaska in late August and early September.

Savannah Sparrow *(Passerculus sandwichensis)*

The Savannah Sparrow commonly breeds inland on the tundra and less frequently on the arctic coast of Alaska. An individual of this species was collected by marine science technicians aboard the GLACIER at 72°59′ N, 167°36′ W, 110 miles from the nearest land on 6 September. On 24 September a bird, presumed to be this species, circled the ship 10 miles northwest of Wainwright (fig. 14).

Snow Bunting *(Plectrophenax nivalis)*

A flock of 15 Snow Buntings was feeding on Beach Ryegrass *(Elymus mollis)* on the snow-covered frozen beach at Point Lay on 26 September. Six specimens, one an immature, were collected (table 11). This species was not observed on the second visit to Point Lay on 5 October when more snow covered the ground. Most Snow Buntings leave arctic Alaska on migration by mid-September.

Polar Bear *(Thalarctos ursinus)*

Polar Bears live largely on heavy pack ice and in nearby water and are therefore absent from the southern Chukchi during the ice-free summer months when they move north with the drifting pack. They are most common during winter when they are hunted by eskimos and sportsmen. The populations are apparently declining because of increased trophy hunting from airplanes. Gravid females retire inland during winter where they whelp and, in late March, they and their cubs join the solitary males and barren females on the ice.

We observed Polar Bears on four occasions either on the pack ice or swimming near it. Two single individuals were seen near Point Barrow 25 September. Three bears, presumably a mother and two nearly full grown immatures were at 71°08′ N, 158°55′ W the following day (fig. 37), and while on our deepest penetration into the pack ice we saw another single bear at 70°34′ N, 163°16′ W on 1 October.

Polar Bears feed on Seals, young Walruses, fish, and carrion that they find on the ice or in nearby waters.

Walrus *(Odobenus rosmarus)*

The shallow waters of the Chukchi Sea are the main summer ground of the Walrus in the Pacific sector. Most females and young stay in the western Chukchi while the majority of individuals in the area of Barrow are males. The species is unusual east of Barrow. Walrus move north in the spring and early summer on ice floes reaching Point Barrow in mid-July and start their southward migration toward the Bering Sea in mid-September (Brooks, 1954).

We observed Walrus primarily in the northeast portion of the study area (fig. 38). All large groups were seen in ice areas and most were hauled out on ice floes (fig. 39). The largest single sighting was of a loose concentration of approximately 525 individuals seen 25 miles northwest of Point Lay. We observed females with small young on six occasions throughout the cruise.

Walrus feed by foraging in water up to 40 fathoms deep for benthic organisms, particularly bivalve molluscs, other invertebrates and occasionally Arctic Cod. At Barrow the mollusc *Mya truncata* is their primary food (Brooks, 1954). They stir up bottom sediments with their tusks, sort out food with their lips and whiskers and presumably suck out the contents rejecting the shells.

Seals *(Phocidae)*

Seals were seen throughout the cruise though few were observed well enough to be reliably identified to species (fig. 40). The Harbor *(Phoca vitulina)*, Ringed *(Pusa hispida)*, Ribbon *(Histriophoca fasciata)* and Bearded Seals *(Erignathus barbatus)* are found in the Chukchi all year with the Ringed Seal being the most common and the Ribbon only a rare vagrant.

The three common Chukchi species appear to be ecologically distinct. The Harbor Seal is an inshore species frequenting estuaries and sand bars. It avoids heavy ice and feeds largely on fish, the species varying seasonally. Presumably seals seen in the open waters of the lagoons and near the barrier beach at Point Lay on 26 September and 5 October were this species. The Ringed Seal frequents open water leads in areas of fast ice but avoids the open sea and floating ice. It feeds on small pelagic crustaceans and to a lesser extent on fish including Arctic Cod. The many seals observed swimming near ice offshore were identified as this species. The Bearded Seal inhabits shallow waters near coasts and unlike the other two species, displays little gregariousness. Individuals rest on beaches and ice floes and although they do not migrate, they tend to move north and south with the drifting ice. Their food consists of benthic organisms-crustaceans, holothurians, clams, snails, whelks, octopus, and bottom fish. The majority of the numerous individuals that were hauled out on the ice on transects late in the cruise was identified as Bearded Seals on the basis of muzzle shape. No Ribbon Seals were seen on the cruise.

Whales *(Cetacea)*

We observed whales on only three occasions during the cruise. At 71°08′ N, 158°55′ W on 24 September and at 70°34′ N, 163°16′ W on 1 October we tentatively identified single individuals as Bowhead Whales *(Balaena mysticetus)*. Both were near pack ice. A group of five to eight Killer Whales *(Orcinus orca)* was observed in a lead in the ice at 70°05′ N, 168°53′ W on 8 October pursuing a female Walrus with a young one on her back.

The Bowhead Whale is associated with ice and is present in the Chukchi Sea during the winter, but tends to move even further north in the summer. It is hunted by the eskimos but is protected from commercial exploitation. During the summer this baleen species, which feeds on small planktonic organisms, is replaced by the Grey Whale, *Eschrichtius gibbosus* in the Chukchi. This latter species presumably already had migrated south in late September for we saw none during the cruise. A few Killer Whales presumably stay in the Chukchi all year wherever there is open water. They travel in groups and feed on seals, young Walruses and even porpoises and other whales.

MIGRATION AND POST-BREEDING DISPERSAL MOVEMENTS

We saw no shearwaters or fulmars, except in the Bering Strait, no pond ducks nor geese, no shorebirds save phalaropes, no Arctic Terns, and no Grey Whales—all species that have been commonly recorded in the Chukchi Sea by other observers earlier in the season. The only Sabine's Gulls that we saw there were in the

Barrow area early in the cruise. Jaegers and phalaropes were infrequent and generally seen only during the first 2 weeks of the cruise in the study area. Fewer Kittiwakes were seen than had been found by other observers. On the other hand, among the birds we saw most commonly was Ross' Gull, an arctic species that does not breed in the Chukchi Sea at all, and the Ivory Gull that breeds only on Herald Island in the western Chukchi. Many of the loons, Oldsquaw and eider ducks, Glaucous Gulls, and alcids were well offshore in relative abundance, farther from land than one would expect from other published accounts.

All of these distribution anomalies were the result of various sorts of seasonal movements. Southward fall migration had already taken place or was well advanced in the less tolerant species that feed or breed in the arctic but move to temperate latitudes with the onset of cold weather in the fall. These included the Slender-billed Shearwater, Northern Fulmar, most ducks, geese, phalaropes, jaegers, Sabine's Gull, Arctic Tern, and Grey Whale. East-west dispersal or migration accounted for the presence of Ivory and Ross' Gulls in the Chukchi where they may winter among the open leads in the pack ice. Post-season dispersal of birds that were released from dependence on land for rearing young probably accounts for the pelagic records of a number of species that we recorded, but which were not regularly recorded far from land during the breeding summer season. These include the Oldsquaw and eiders, Glaucous Gull, murres, guillemots and Horned Puffin. The Parakeet and Crested Auklets were present considerably north of their breeding grounds, the latter species in relative abundance. This post-breeding dispersal spreads predation pressure on prey species over a much greater range, at a time when food may start to become scarce, than during the breeding season, at the height of plankton and fish abundance.

ICE AFFINITIES

Ice was a major factor affecting the distribution and abundance of some species in the study area. Guillemots, for instance, were found almost exclusively at the edge of the pack ice (figs. 26 and 32). Some of the gulls, likewise, were more abundant near the ice than in open water. In order to assess the significance of the affect of ice on the distribution of gulls, watches were divided into two categories; those with ice and those in open water in which no ice was visible from the ship. The categories were tested statistically by X^2 (chi square) (table IV). Watches in heavy fog or those in new or grease ice were presumed atypical and were not included in the totals.

On transects Ivory and Ross' Gulls showed a decided preference for ice areas while the Glaucous Gull showed no significant preference, and the Kittiwake was found primarily in open water. At stations Glaucous, Ivory and Ross' Gulls showed no significant preference, and Kittiwakes avoided ice. The partly contradictory results may be the resemblance of a white icebreaker to ice or the natural attraction of gulls to a standing ship. Observations from a moving ship, therefore, probably provide a better indication of a species' ice affinities than those from a standing ship.

The presence of Ivory and Ross' Gulls in ice areas is not surprising in that both species spend much of the year in the pack ice and are adapted to feeding on organisms found at the surface in ice areas. Furthermore, ice may provide secure roosting and resting sites for these two species (fig. 24). The Ivory Gull was only rarely seen swimming, but it frequently perched on ice cakes (fig. 20). That ice had little affect on the distribution of Glaucous Gulls probably is due to its association with land and its relatively unspecialized feeding habits. The preference of Kittiwakes for open water could not be due to the presence of food, since the Arctic Cod, *Boreogadus saida*, the only food item found in their stomachs, occurs closer to the surface in ice areas. The Kittiwake was the only gull whose flying ability was not visibly hindered by high winds that we encountered on many of the open water watches, and there is no evidence that this pelagic species needs land or ice for roosting outside the breeding season.

FOOD HABITS

Although a number of species of diverse families of marine birds occurs in the Chukchi Sea in fall, the primary foods of all but the ducks are pelagic crustaceans and small fish,

mainly Arctic Cod, *Boreogadus saida* (table V). The methods used by various predator species to capture their prey, and the depths at which they feed, differ (table VI), so that they may not be in competition for the same food resource. It is not known, however, whether predation by higher vertebrates constitutes a significant factor that might limit populations of invertebrates and fish in the Chukchi (Quast in preparation).

ABUNDANCE

We have not yet attempted to convert our line transect counts of the birds and mammals we observed into estimates of total population. Such estimates from line transect data of at-sea observations are frought with hazards (Yapp 1955, Bailey 1965). The major problems are the near impossibility of estimating distance from a moving ship and the differential visibility of various species. For instance, a Walrus or seal on a cake of ice is visible at a greater distance than one in the water. A single adult Ross' Gull flying is far more difficult to see than a Glaucous Gull or a flying loon. Small auklets may be virtually invisible when swimming in rough water, but are conspicuous during flat calms. This makes both our counts of birds seen, and any estimates of birds per unit area based on them, somewhat suspect. Secondly, in order to convert line transect data to absolute density, one needs to assume that birds are distributed at random. This is presumably so for species that pay little attention to ships, such as alcids or loons, but is not so for birds that are attracted to ships or follow in the wake, such as gulls. We used only the largest count of gulls on each station or each 20-minute transect interval for just this reason. The same is true if the environment is not uniform as in the study area where some species were more common near shore than far out at sea, while others congregated near ice. Migrating flocks passing through an area, likewise, do not constitute random distribution. Some of the large flocks of Oldsquaw and eiders that we saw were probably migrating and were a part of the local population one hour and gone the next. Good statistical methods have not yet been devised to account for all of these variables.

On the other hand, it should be possible to compare line transect counts made under similar environmental conditions at different times in the same area in order to obtain estimates of relative abundance in different seasons (see also Bailey 1966, appendix). One can, therefore, compare abundance between species such as the Kittiwake and Ross' Gull, or between areas. Such analyses are being pursued by Divoky.

At any rate, it is apparent that considerable numbers of birds and mammals of some species are present in the Chukchi Sea at this time of the year. A significant fraction of the world population of Ross' Gull probably migrates through or winters in the Chukchi. We saw numerous large pods of Walrus. In one restricted area we are sure that over 500 were present (October 4) because we saw almost all of them at the same time. Estimates of the combined total population of Pacific Walrus, both Siberian and Alaskan *(O. r. divergens)* range between 30,000 and 70,000 (King 1964, Johnson *et al*, 1966). Our observation that day, therefore, may have included between 1/60 and 1/140 of all the individuals of the subspecies in the world.

The resident populations of birds and mammals in the Chukchi may be neither large nor concentrated, except in inshore waters or near the cliffs at Cape Lisburne during breeding. On the other hand, the Chukchi serves as an important migratory pathway for the marine species and many ducks, geese, and shorebirds that breed east of Point Barrow and migrate to the Bering Sea or Pacific Ocean. In addition, it serves as a temporary post-nuptial feeding ground for some species that breed further south. Even during September and October we found that considerable numbers of some species of marine birds and mammals were using the area and we conclude that large scale pollution in the area, in any season, could have an important effect on the higher vertebrates.

ACKNOWLEDGMENTS

We are grateful to the Oceanographic Unit of the U.S. Coast Guard and its director Dr. Merton C. Ingham, for extending the invitation for our participation in WEBSEC–70. We are indebted to Capt. Theodore L. Roberge, the

officers, and crew of the GLACIER for facilitating our work aboard ship. In particular we thank Ensign James R. Beach, Chief Marine Science Technician Lynn Dawson, Chief Boatswain's Mate B. L. Johnson, Engineman 2nd Class A. W. Ipock, and the ship's other Marine Science Technicians and small boat crews. Our participation was made possible by special funding from the Smithsonian Oceanography and Limnology Program. During the first 2 weeks of the cruise we were assisted in making observations by J. Larry Haddock of the U.S. Bureau of Sport Fisheries and Wildlife, Anchorage. Divoky also presented data collected during this study in a master's degree thesis presented to Michigan State University, 1972.

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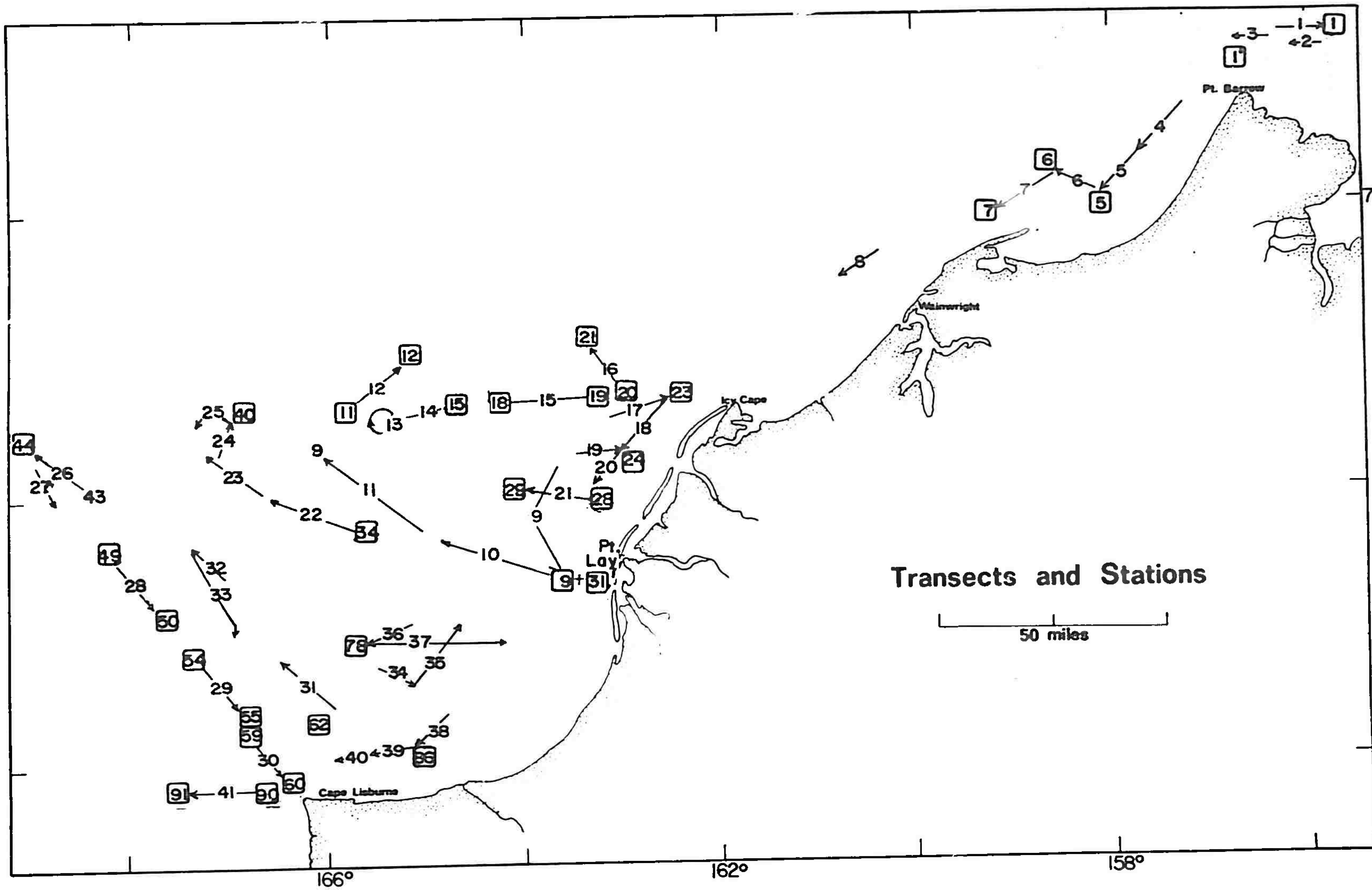

Figure 1.—Transects (numbered arrows) and stations (numbered squares) from Point Barrow to Cape Lisburne on which birds and mammals were observed or collected during WEBSEC-70, 22 September–17 October 1970.

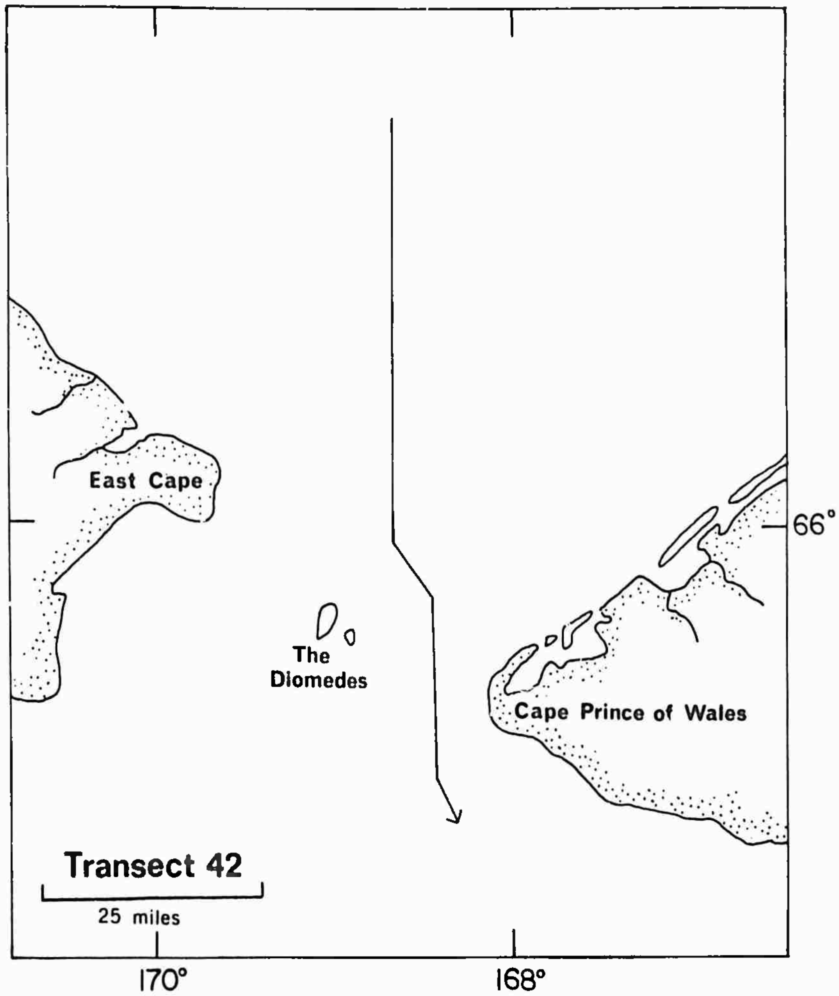

Figure 2.—**Transect 42 through Bering Strait during daylight hours of 18 Oct. 1970.**

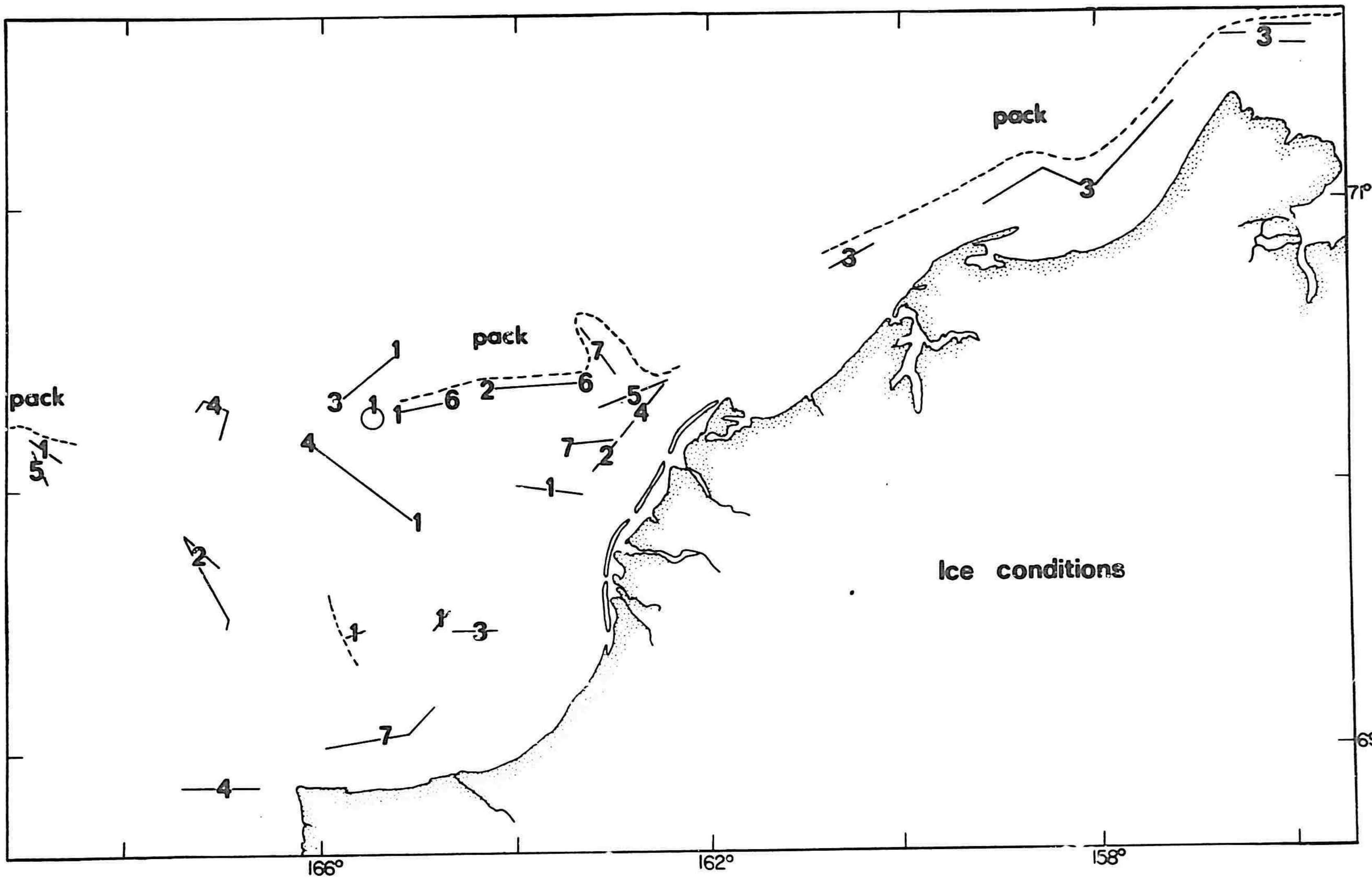

Figure 3.—Ice conditions expressed in oktas (eighths) of total coverage as observed from the GLACIER, 22 September–17 October 1970. Edge of the Arctic pack ice indicated by dotted line.

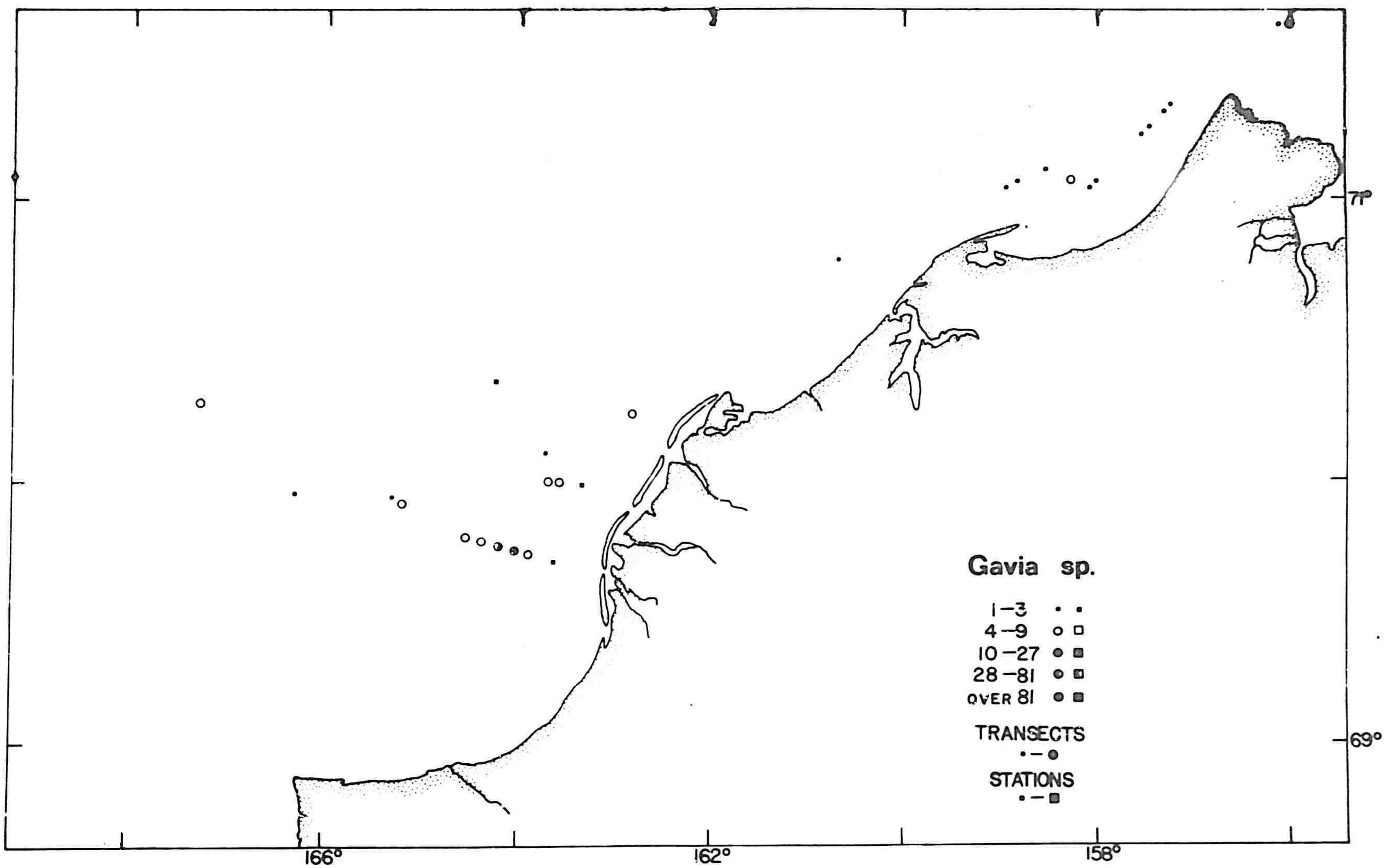

Figure 4.—**Distribution of loons from Point Barrow to Cape Lisburne, 22 September–17 October 1970. Abundance key applies to all other Barrow-Lisburne maps.**

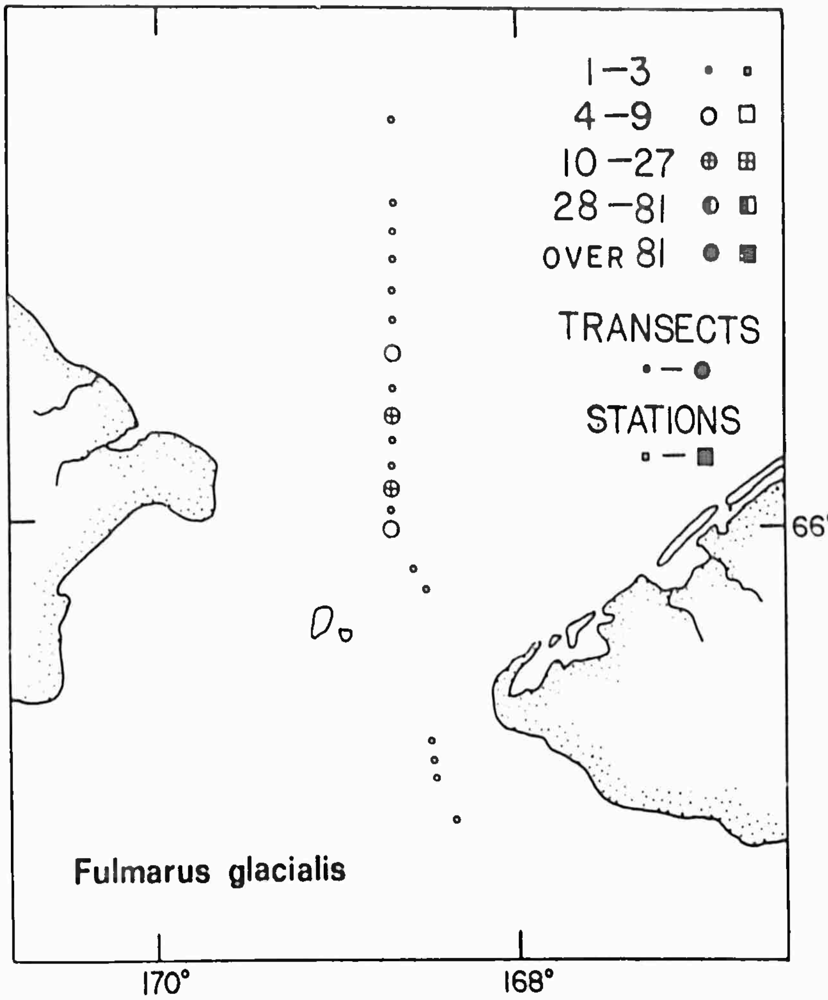

Figure 5.—Distribution of Northern Fulmar in Bering Strait, 18 October 1970. Abundance key applies to all other Bering Strait maps.

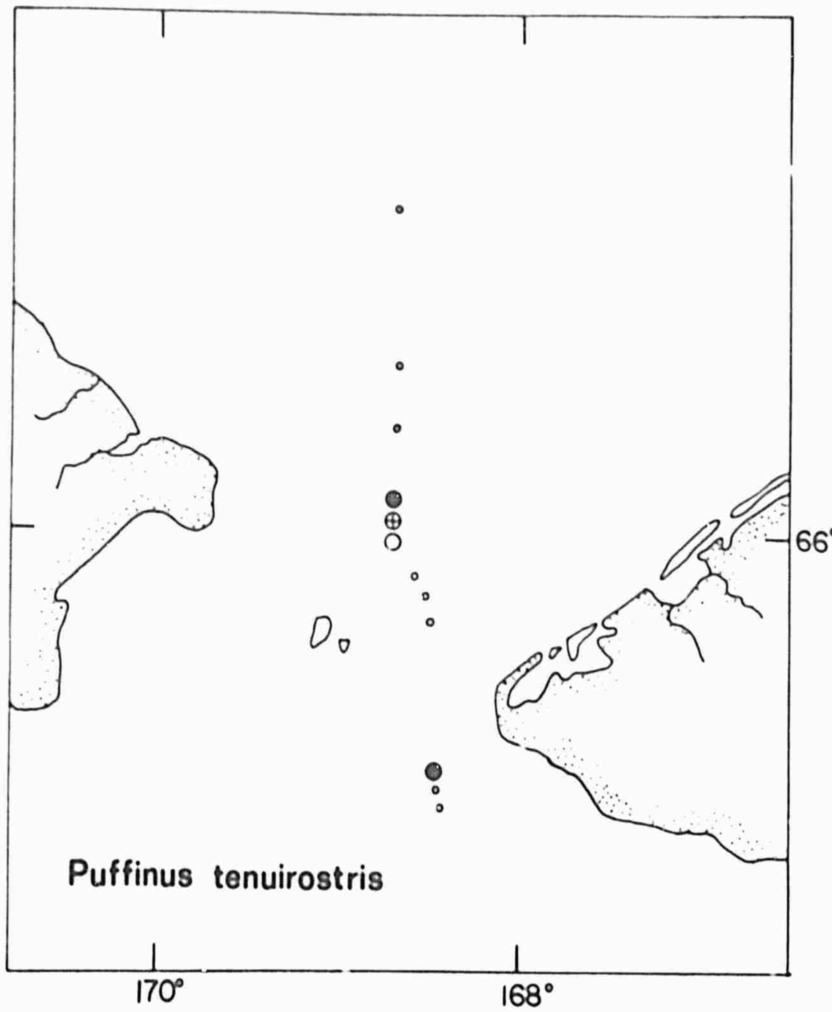

Figure 6.—Distribution of Slender-billed Shearwater in Bering Strait, 18 October 1970.

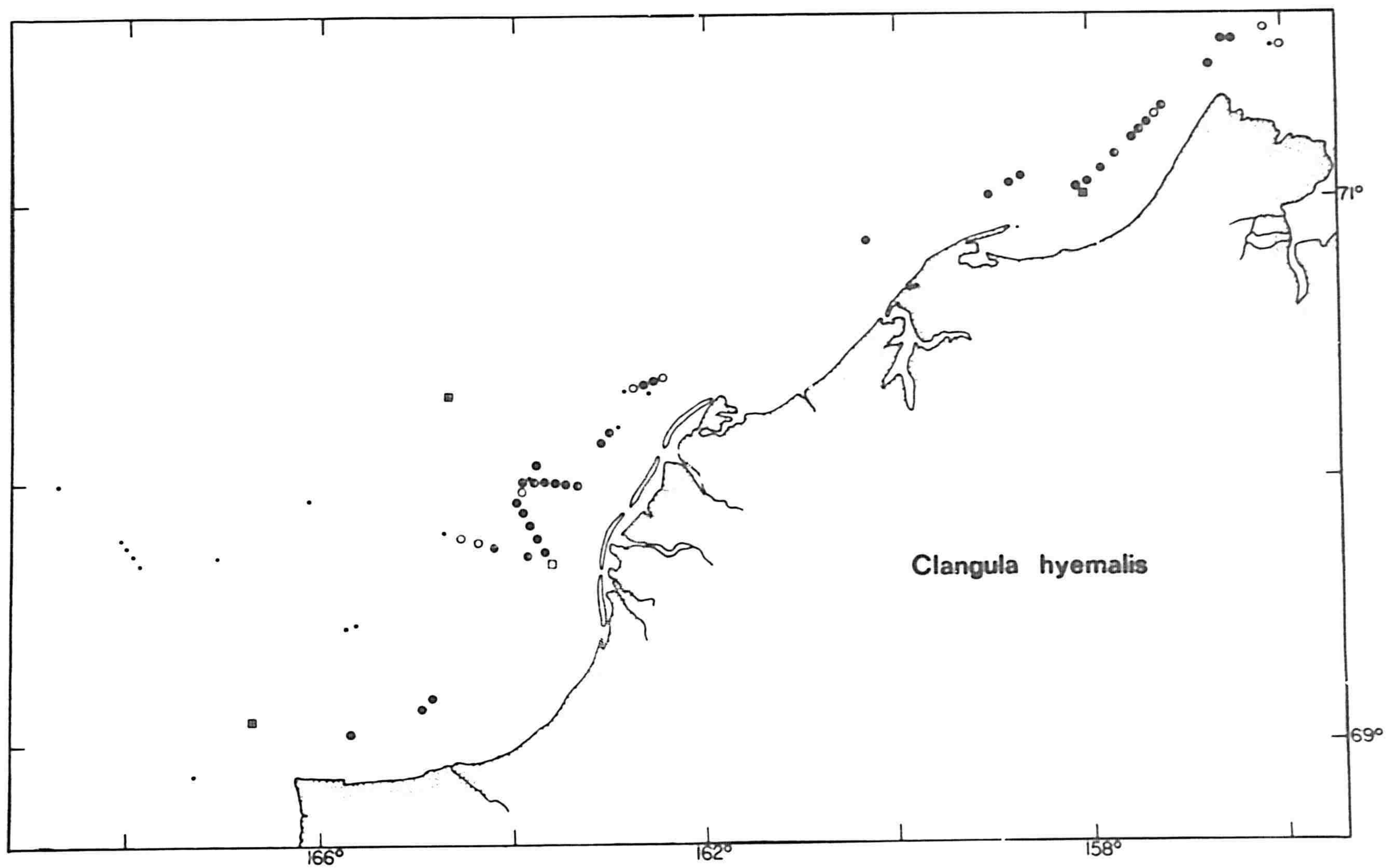

Figure 7.—Distribution of Oldsquaw from Point Barrow to Cape Lisburne, 22 September–17 October 1970. See also Figure 11.

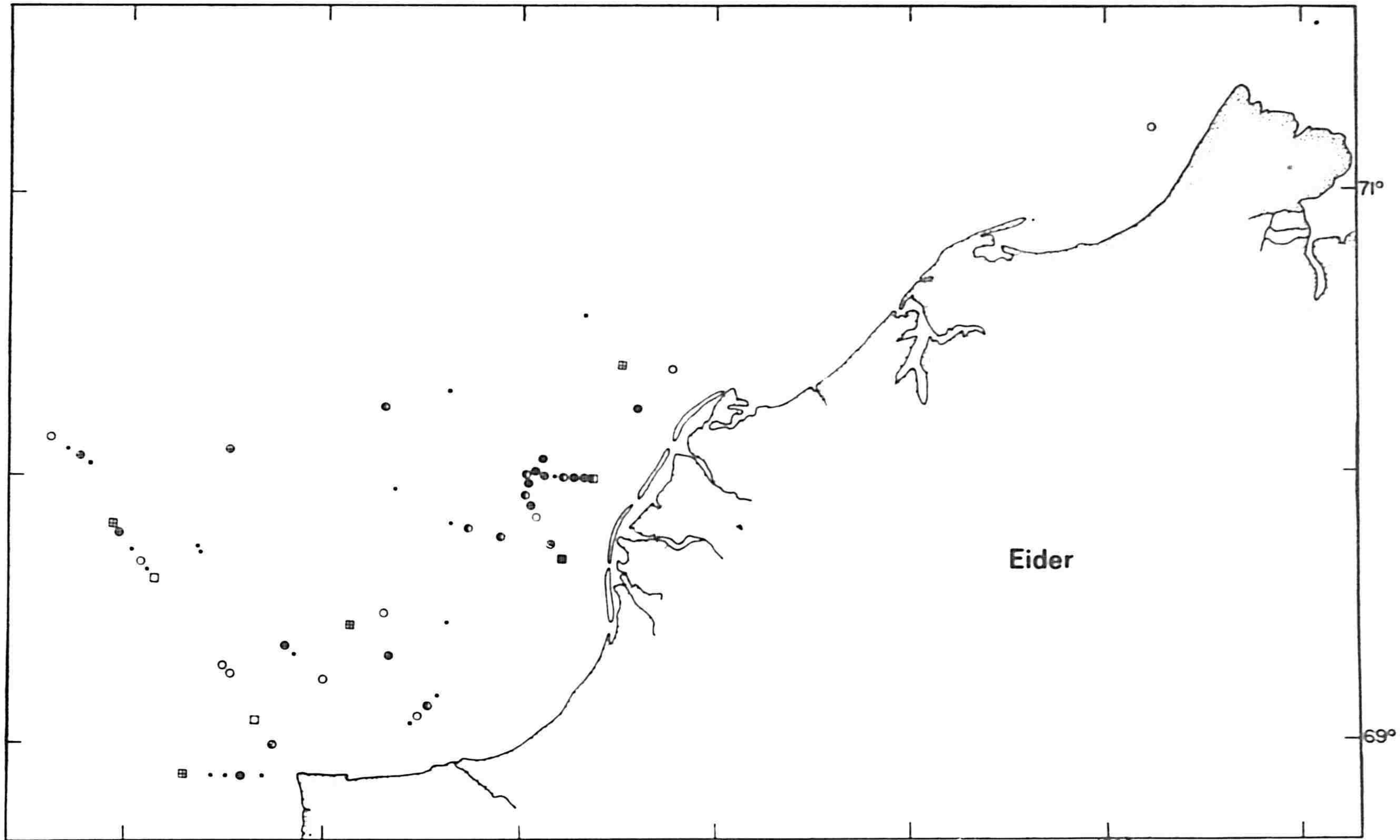

Figure 8.—Distribution of eiders from Poin' Barrow to Cape Lisburne, 22 September–17 October 1970. See also Figure 11.

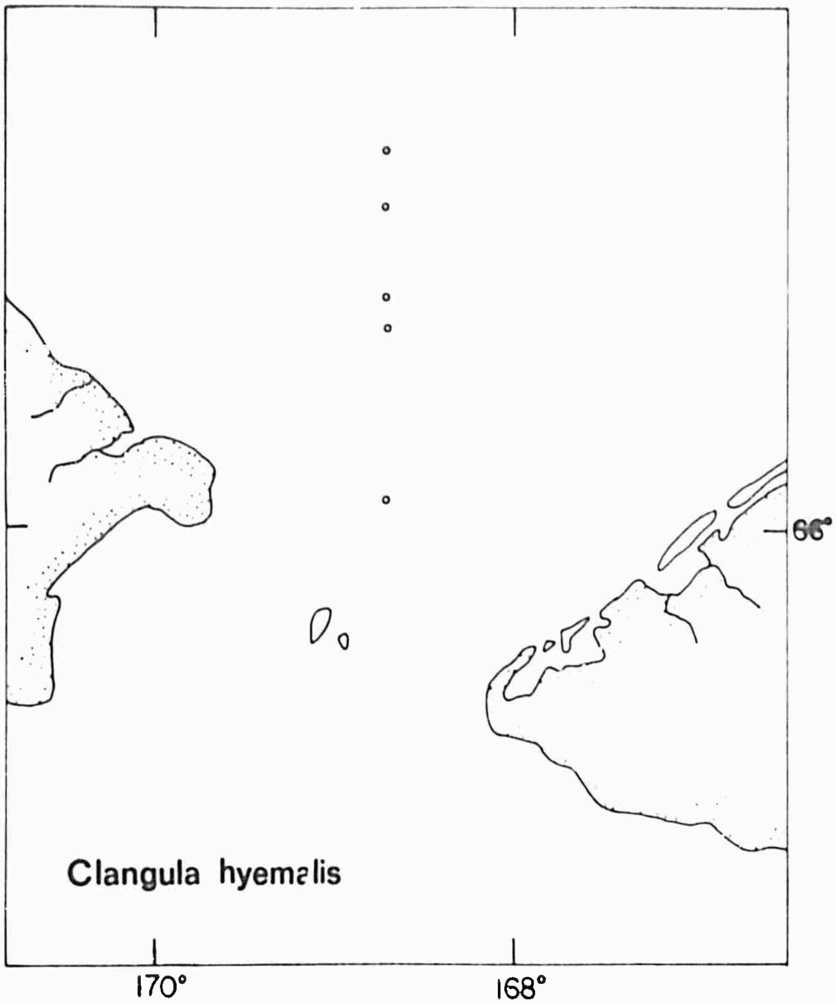

Figure 9.—Distribution of Oldsquaw in Bering Strait, 18 October 1970.

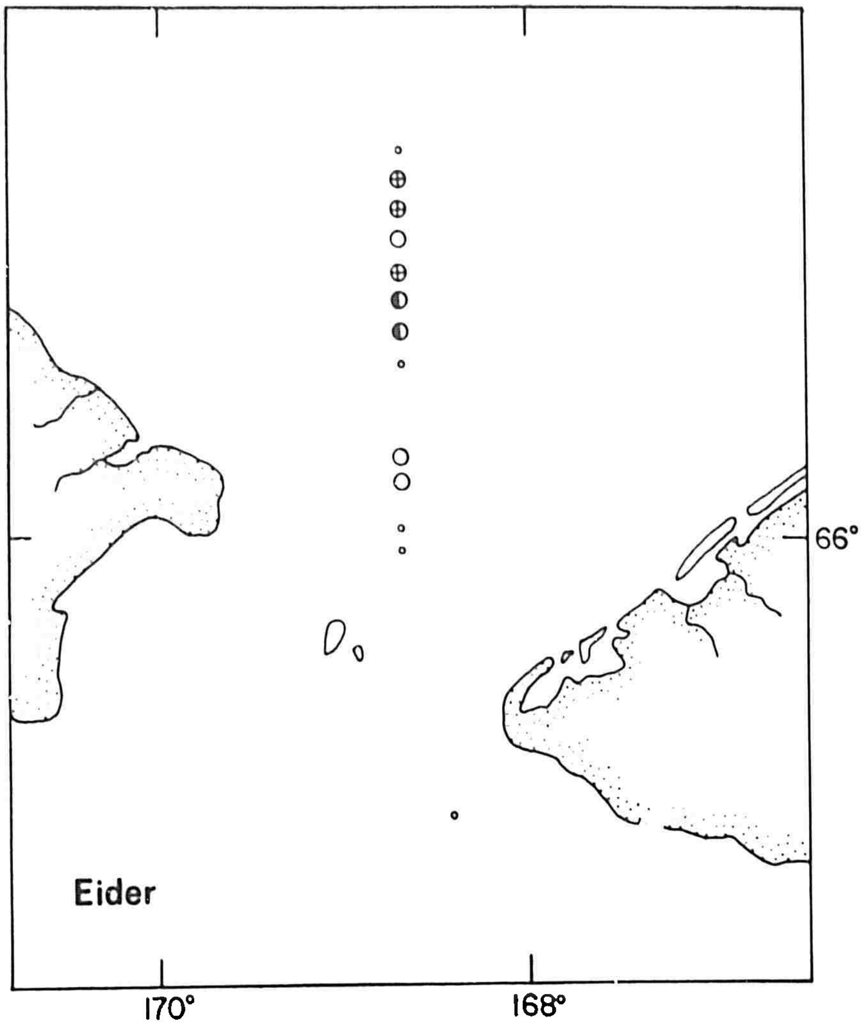

Figure 10.—Distribution of eiders in Bering Strait, 18 October 1970.

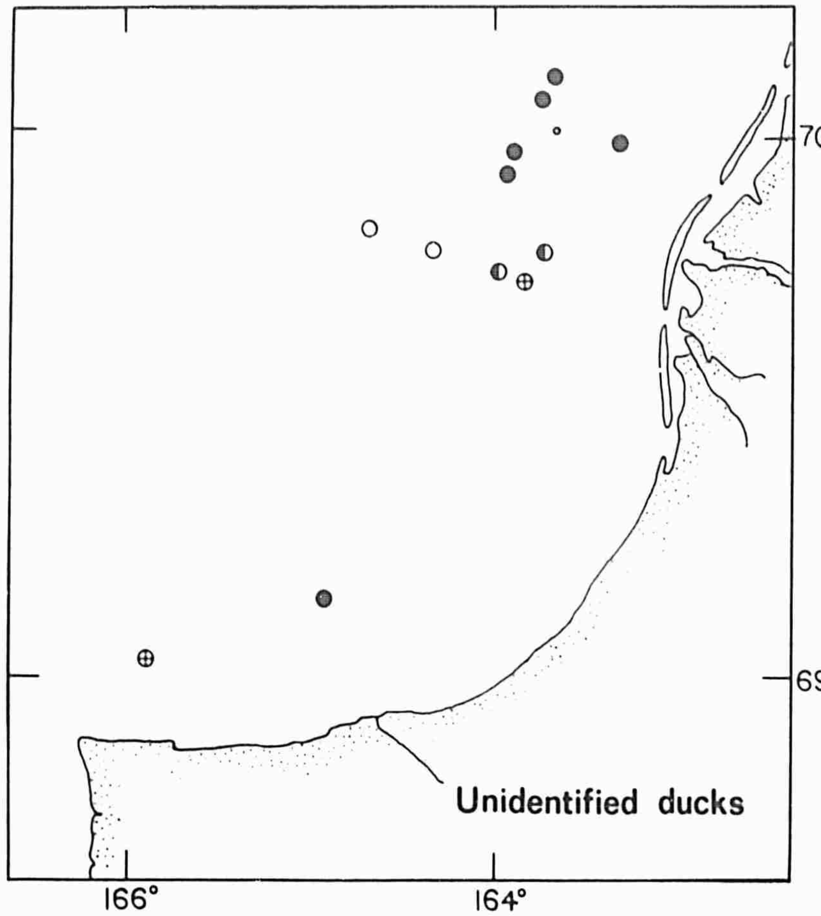

Figure 11.—Distribution of unidentified ducks seen at a distance in the study area, 22 September–17 October 1970. See also Figures 7, 8 and 14.

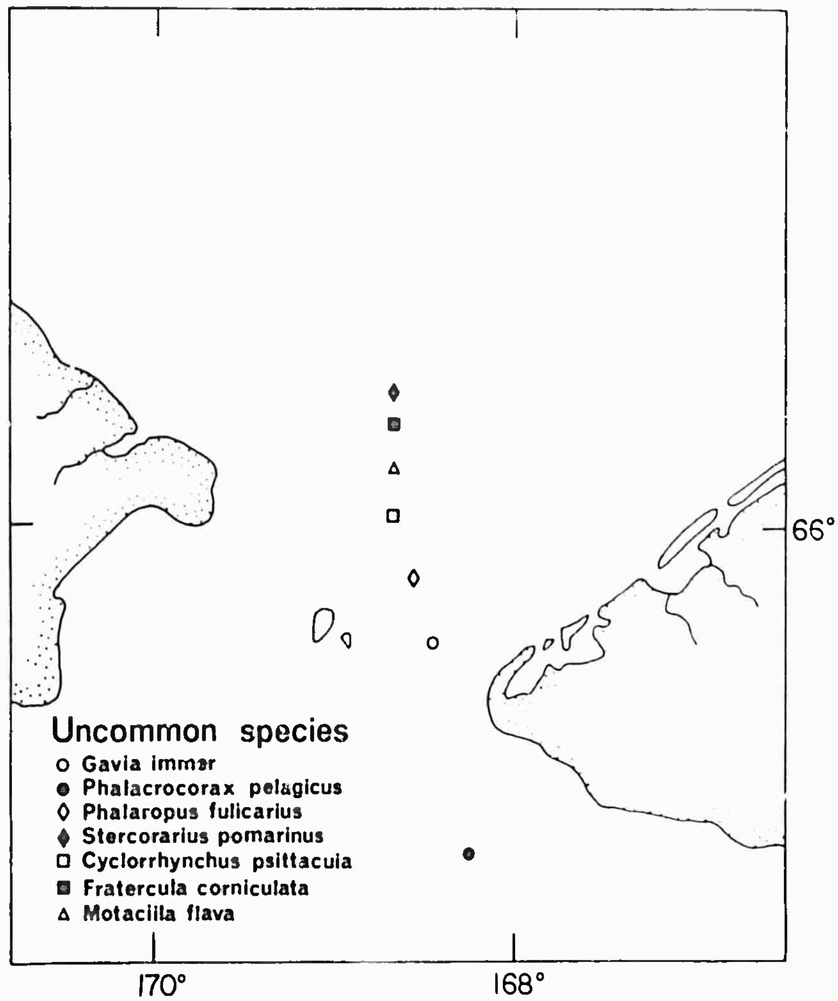

Figure 12.—Distribution of uncommon species in Bering Strait, 18 Oct. 1970.

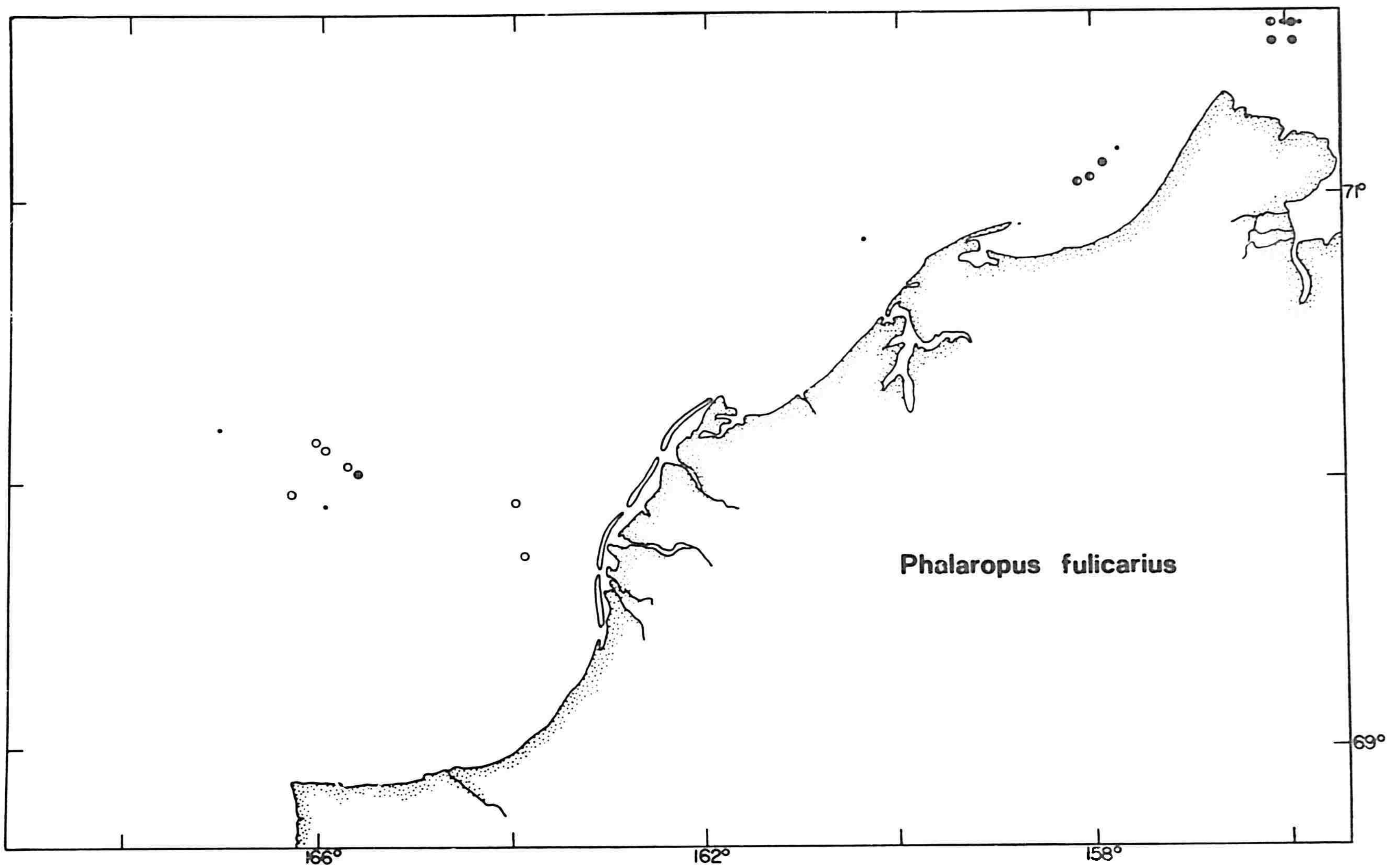

Figure 13.—**Distribution of Red Phalarope from Point Barrow to Cape Lisburne, 22 September–17 October 1970.**

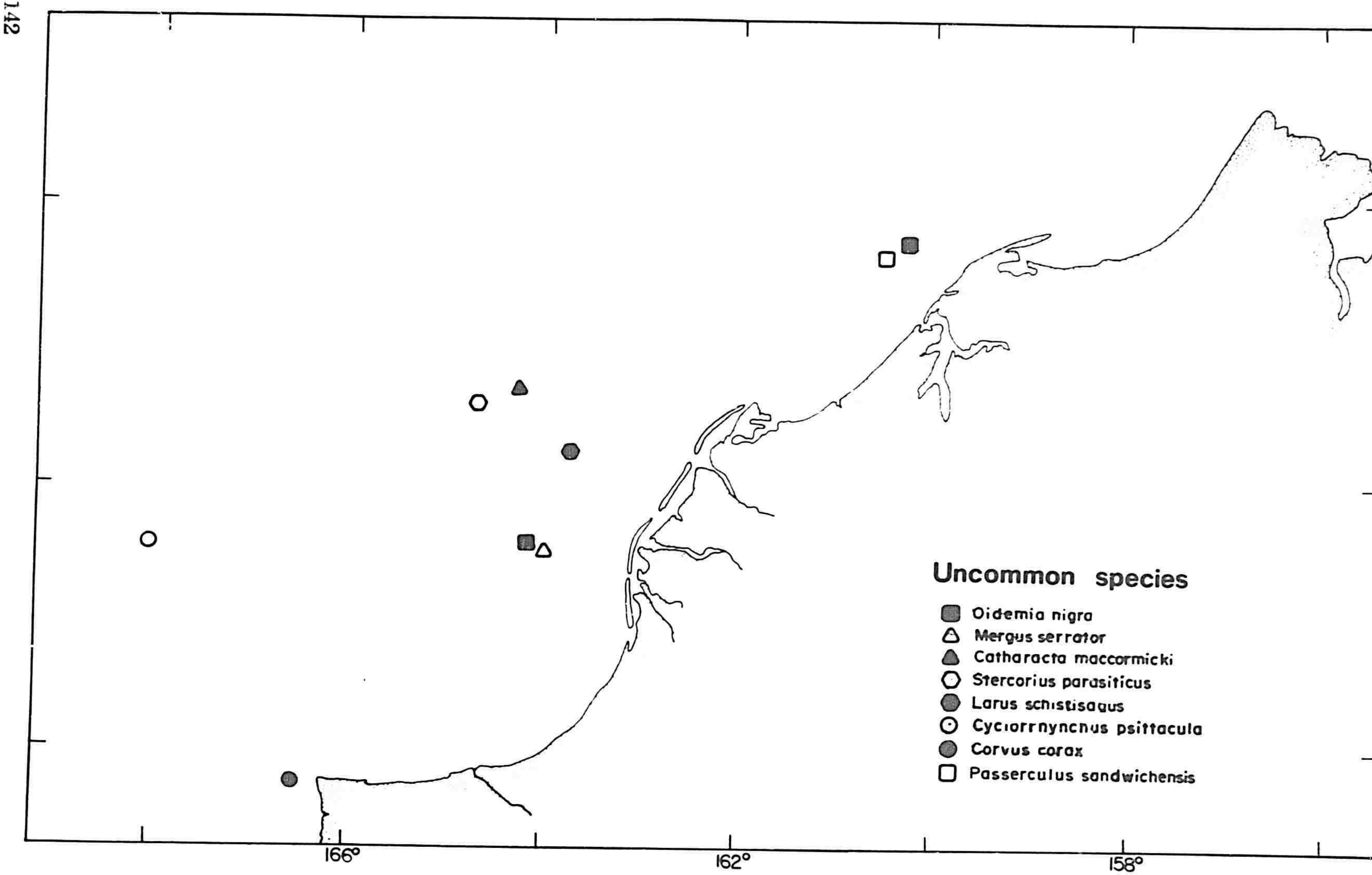

Figure 14.—**Distribution of uncommon species from Point Barrow to Cape Lisburne, 22 September–17 October 1970.**

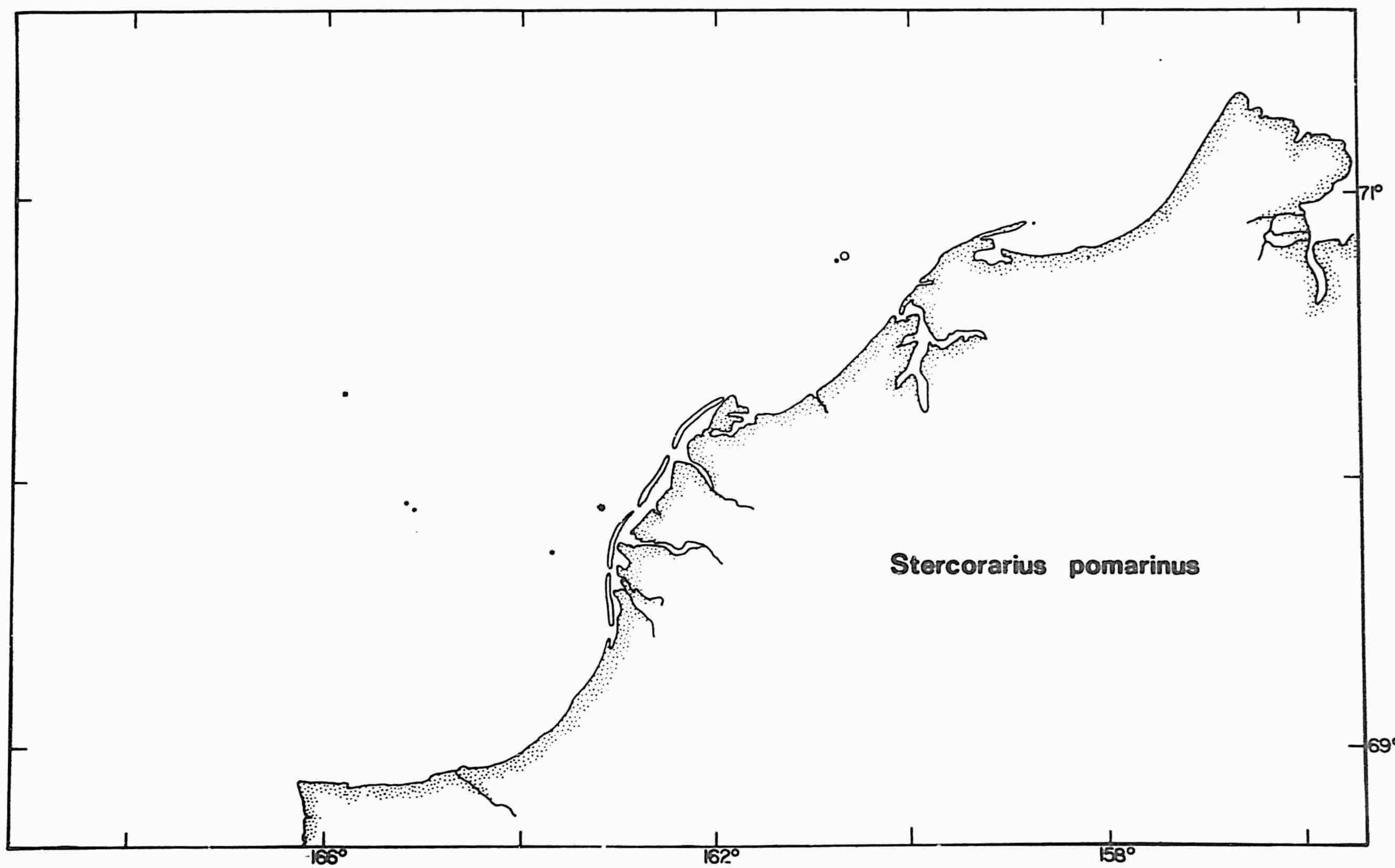

Figure 15.—Distribution of Pomarine Jaeger from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

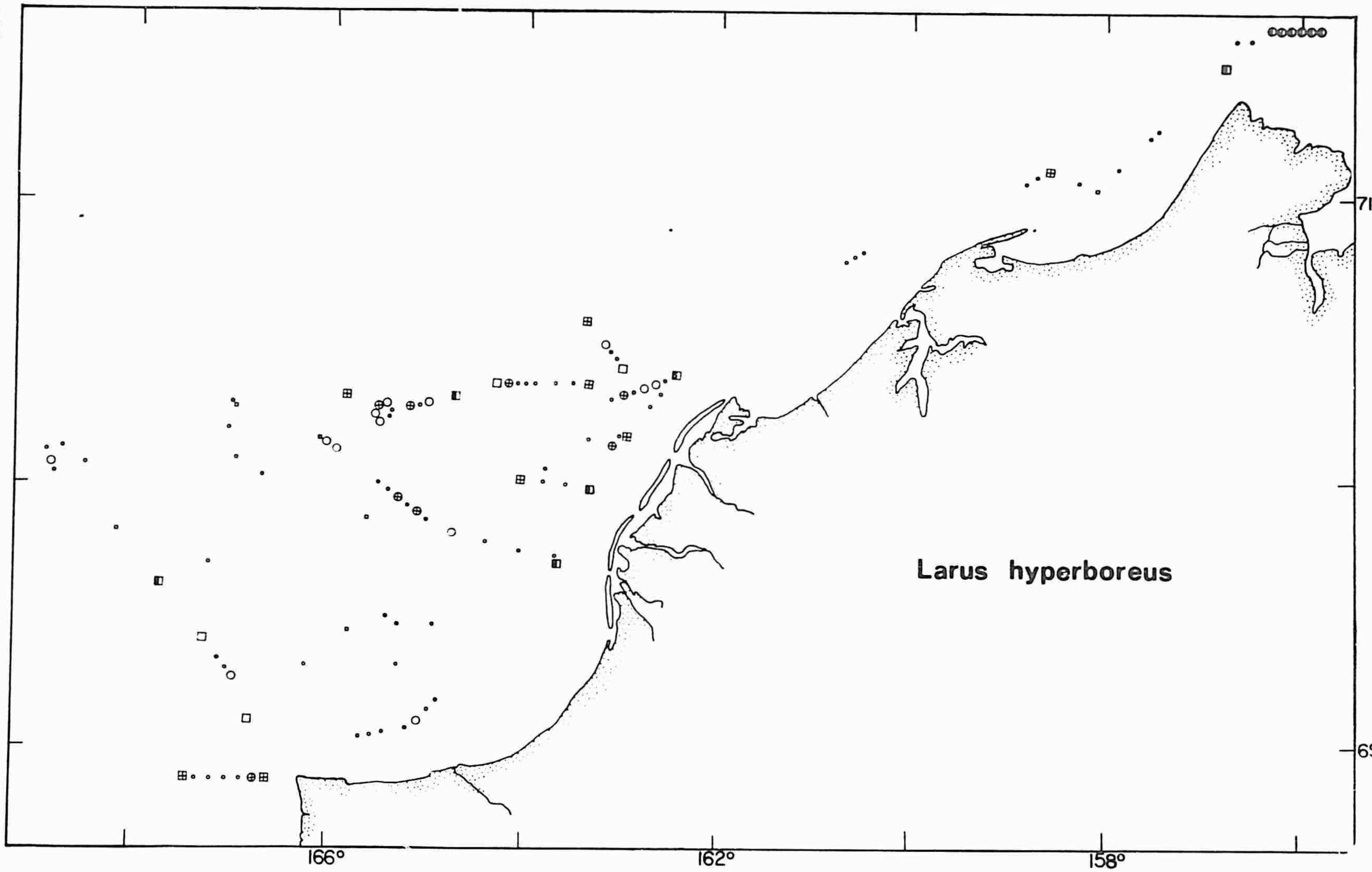

Figure 16.—Distribution of Glaucous Gull from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

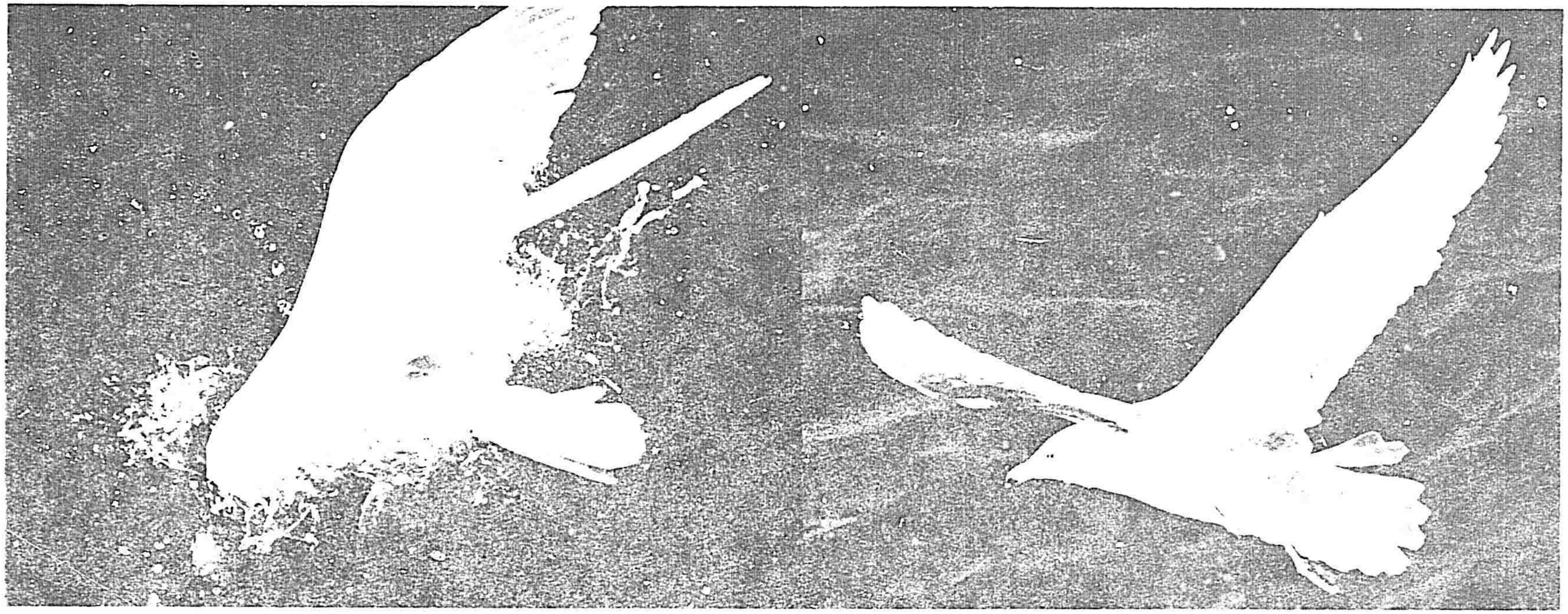

Figure 17.—Glaucous Gull adult (left) feeding on surface and second-year immature in flight.

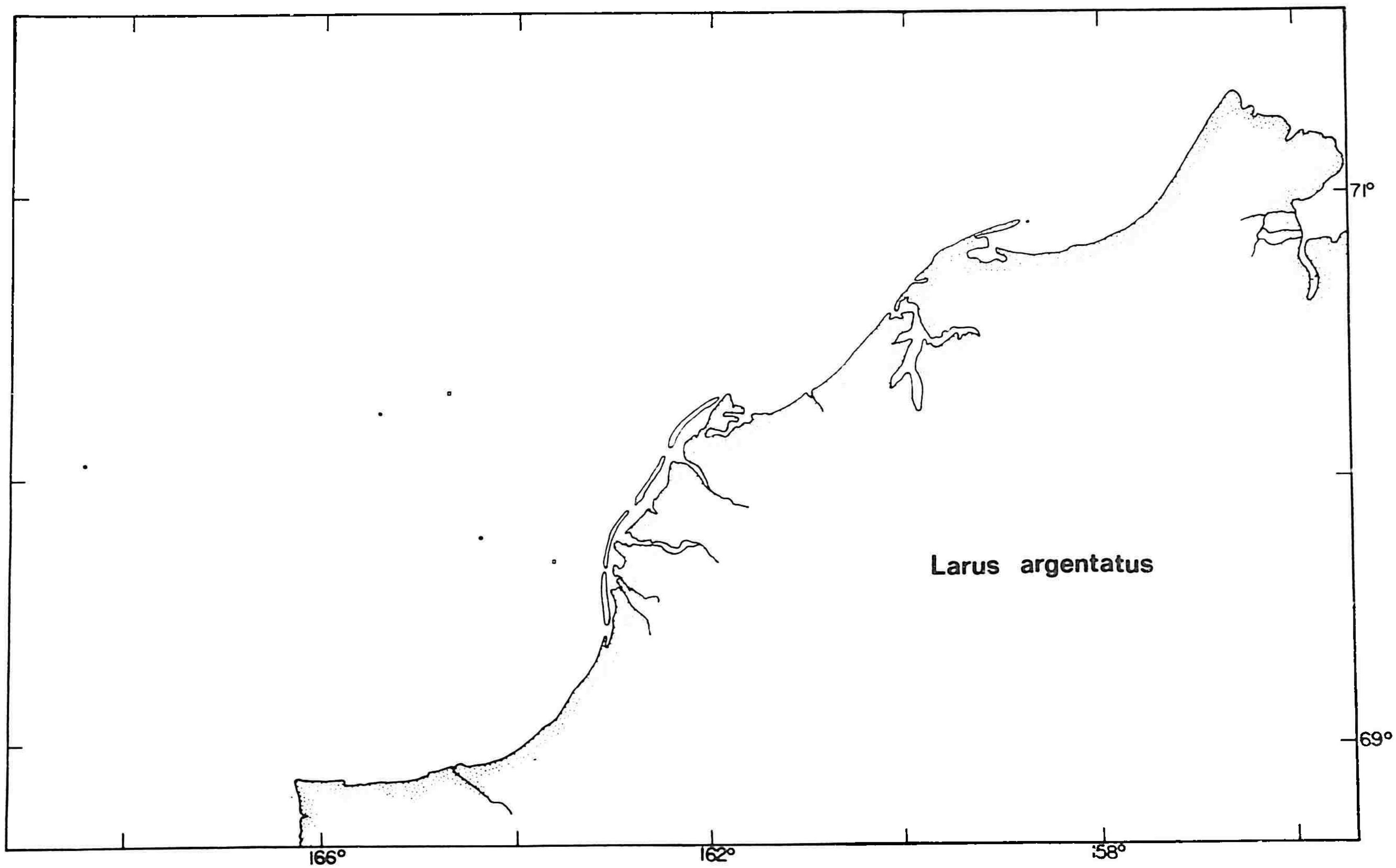

Figure 18.—Distribution of Herring Gull from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

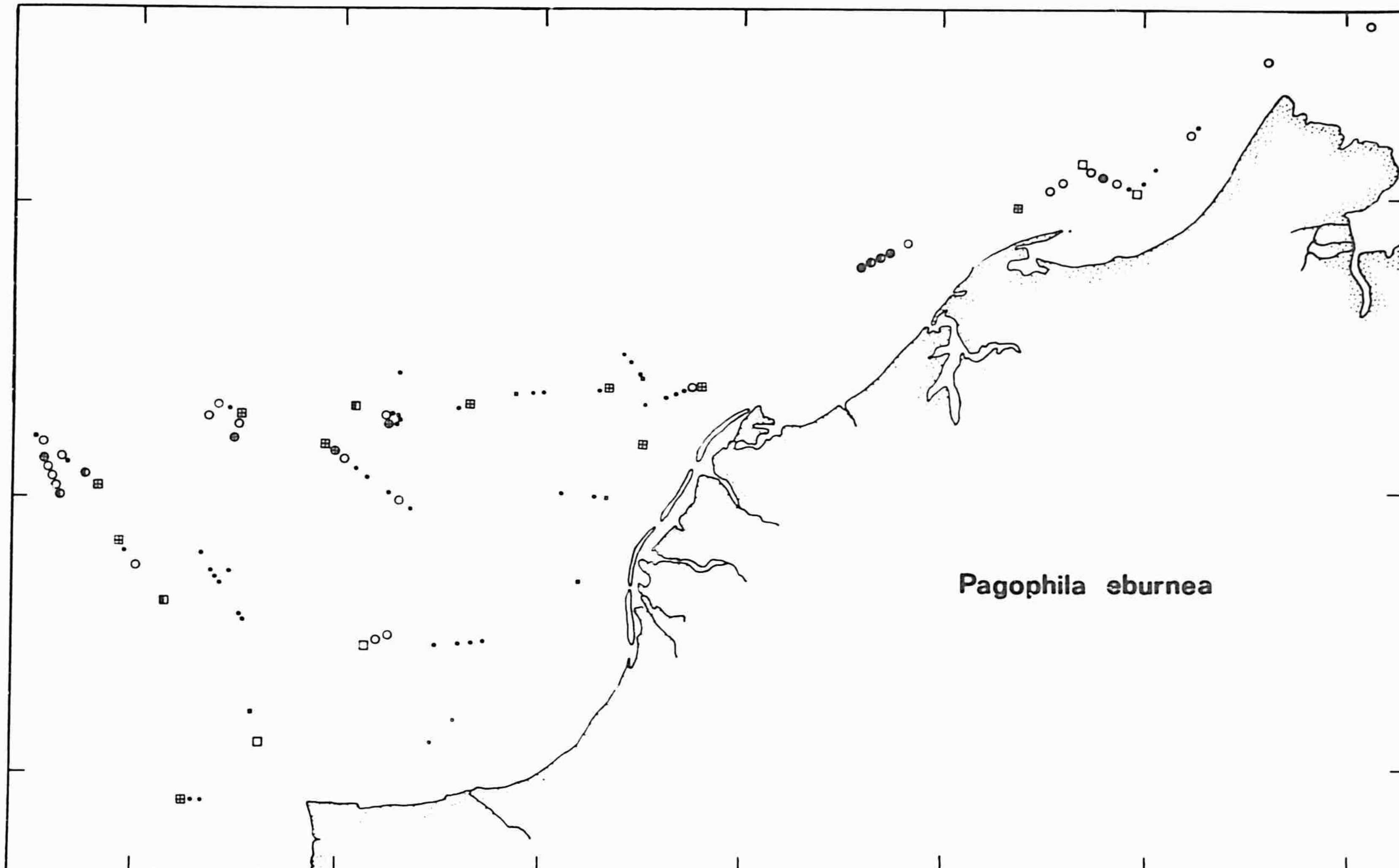

Figure 19.—Distribution of Ivory Gull from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

Figure 20.—Ivory Gull, in flight (left), sitting on ice cake, and swimming (right). Dark-faced individuals are immature

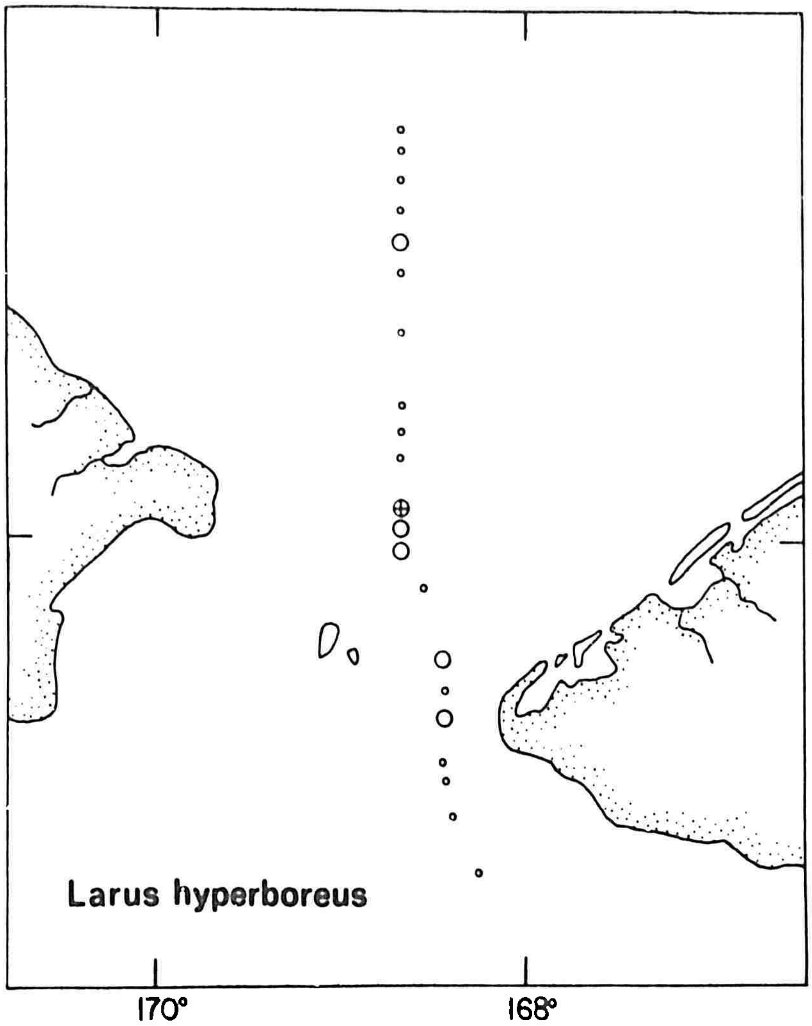

Figure 21.—Distribution of Glaucous Gull in Bering Strait, 18 October 1970.

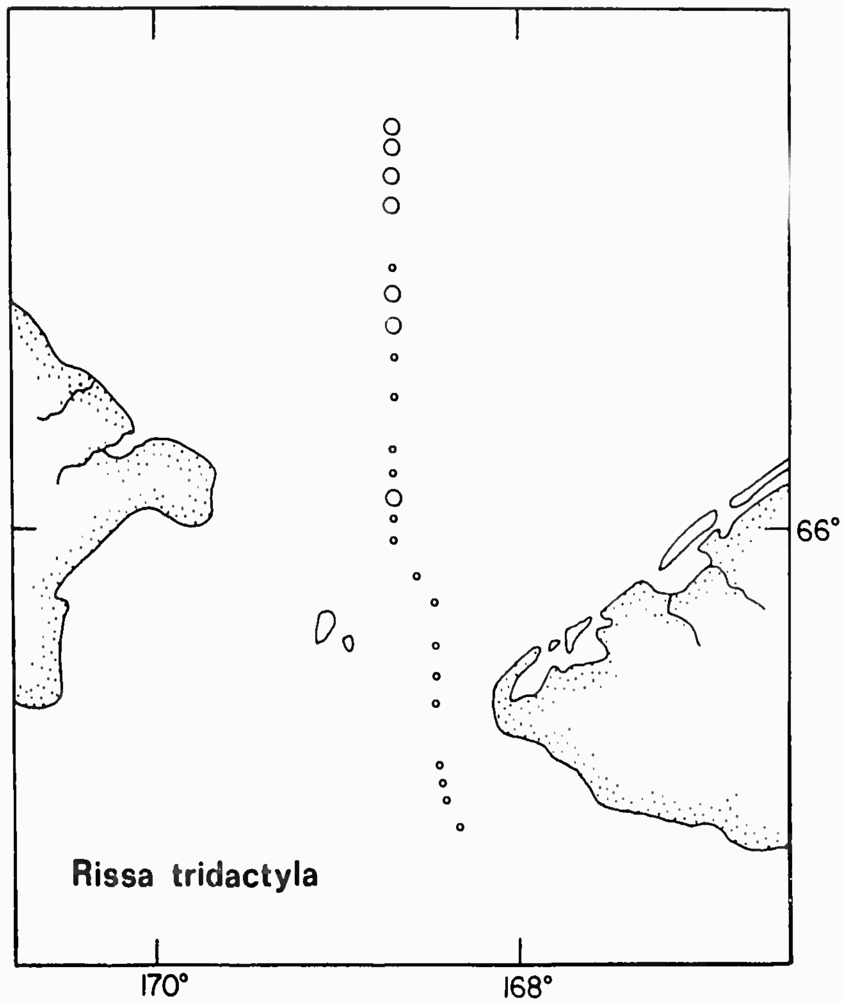

Figure 22.—**Distribution of Kittiwake in Bering Strait, 18 October 1970.**

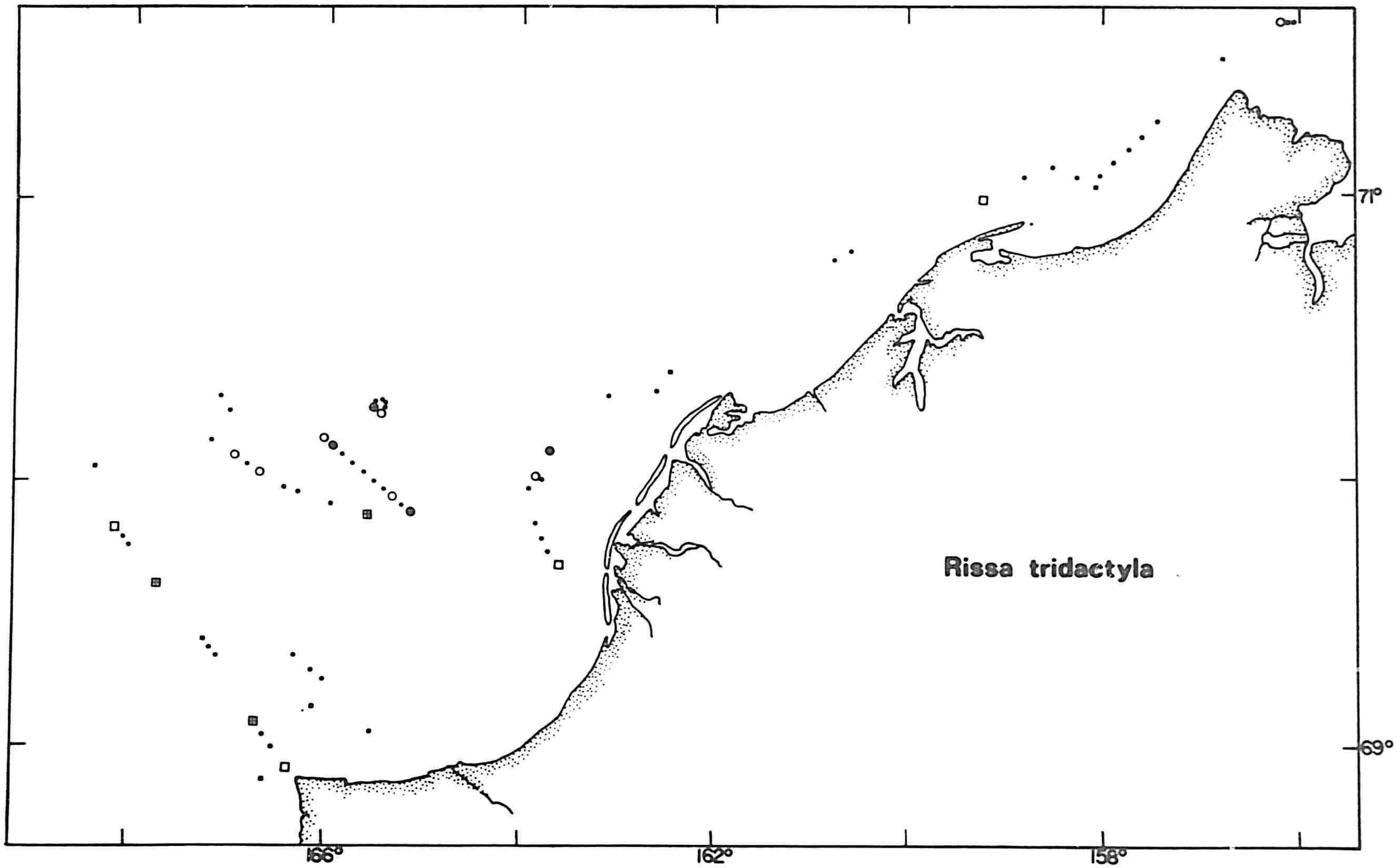

Figure 23.—Distribution of Kittiwake from Point Barrow to Cape Lisburne, 22 September–17 October.

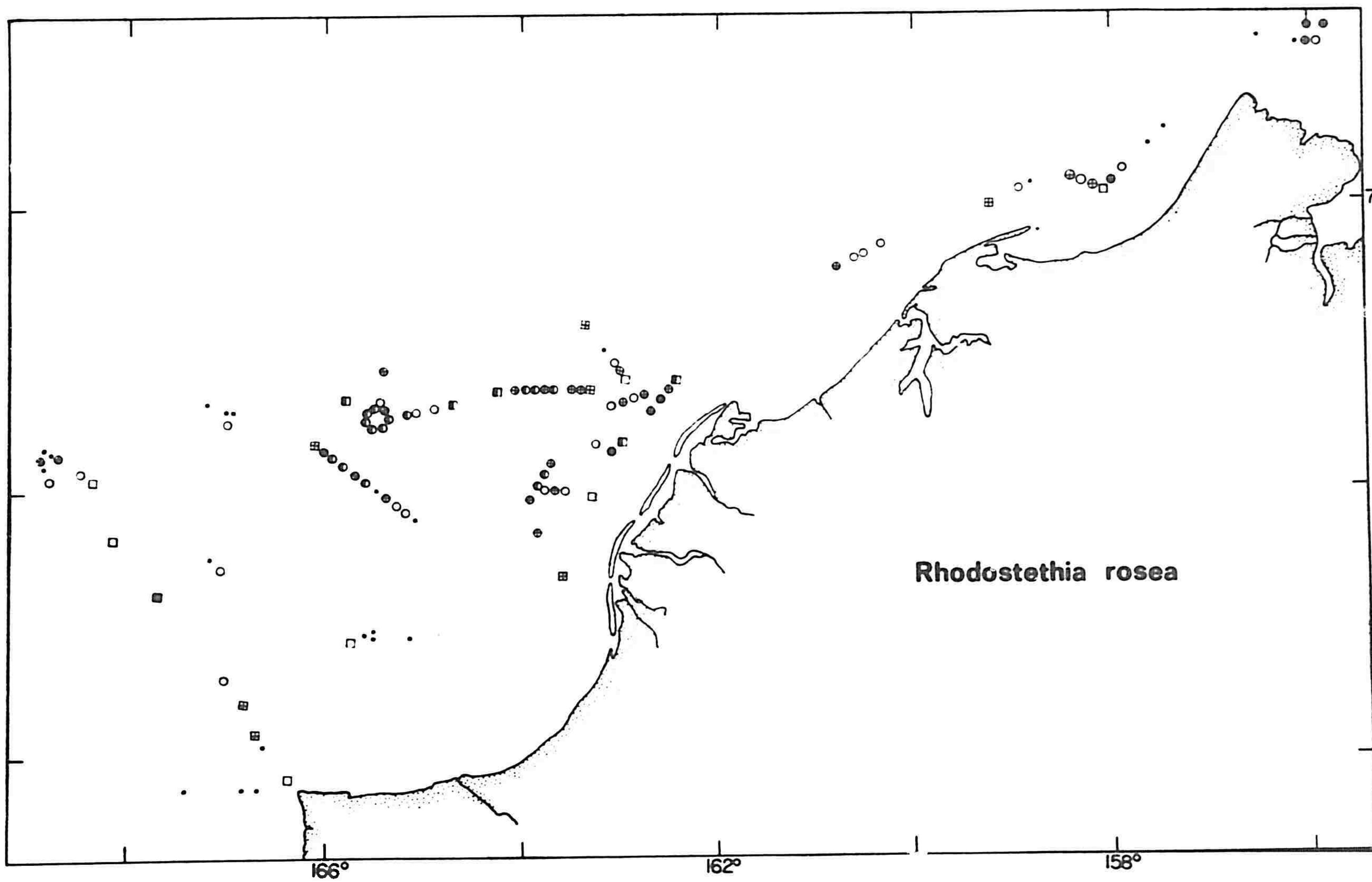

Figure 24.—Distribution of Ross' Gull from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

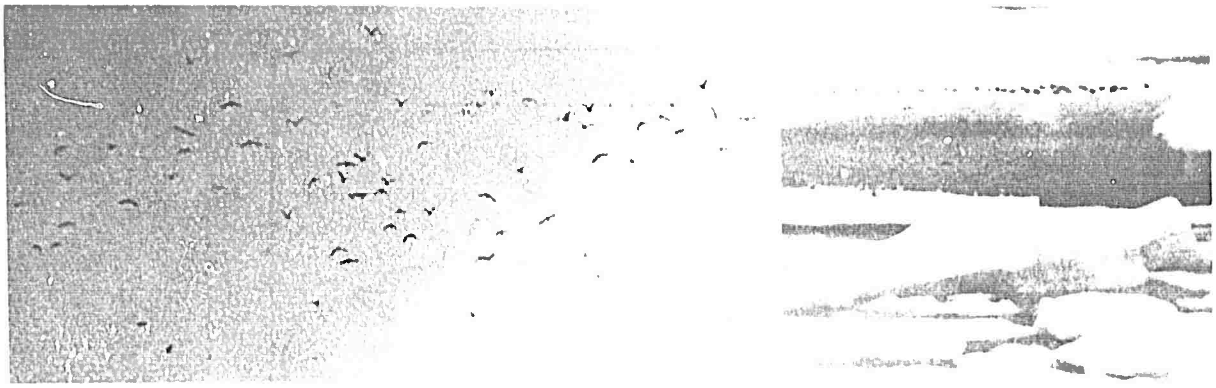

***Figure 25.*—Flocks of Ross' Gulls flying and sitting on an ice floe.**

***Figure 26.*—Immature Ross' Gulls in flight (left and center) and Black Guillemot swimming at ice edge.**

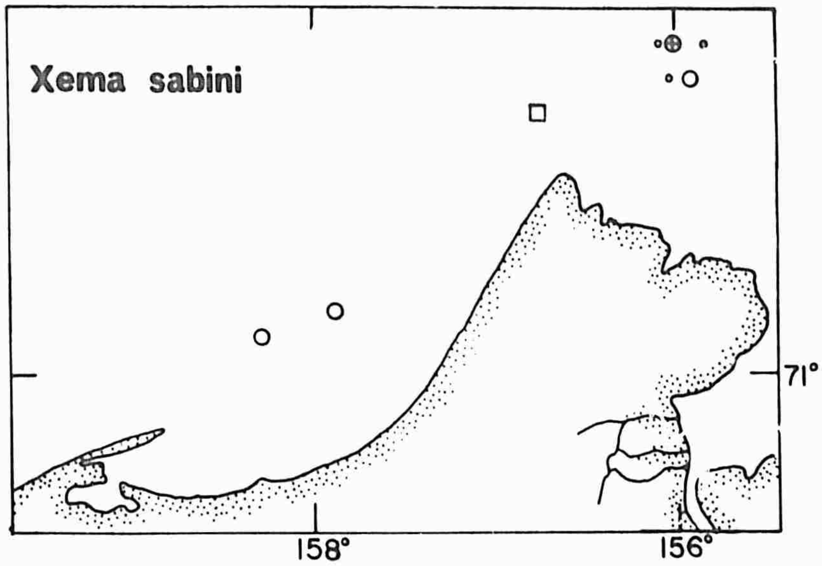

Figure 27.—Distribution of Sabine's Gull near Point Barrow, 23, 24 September 1970.

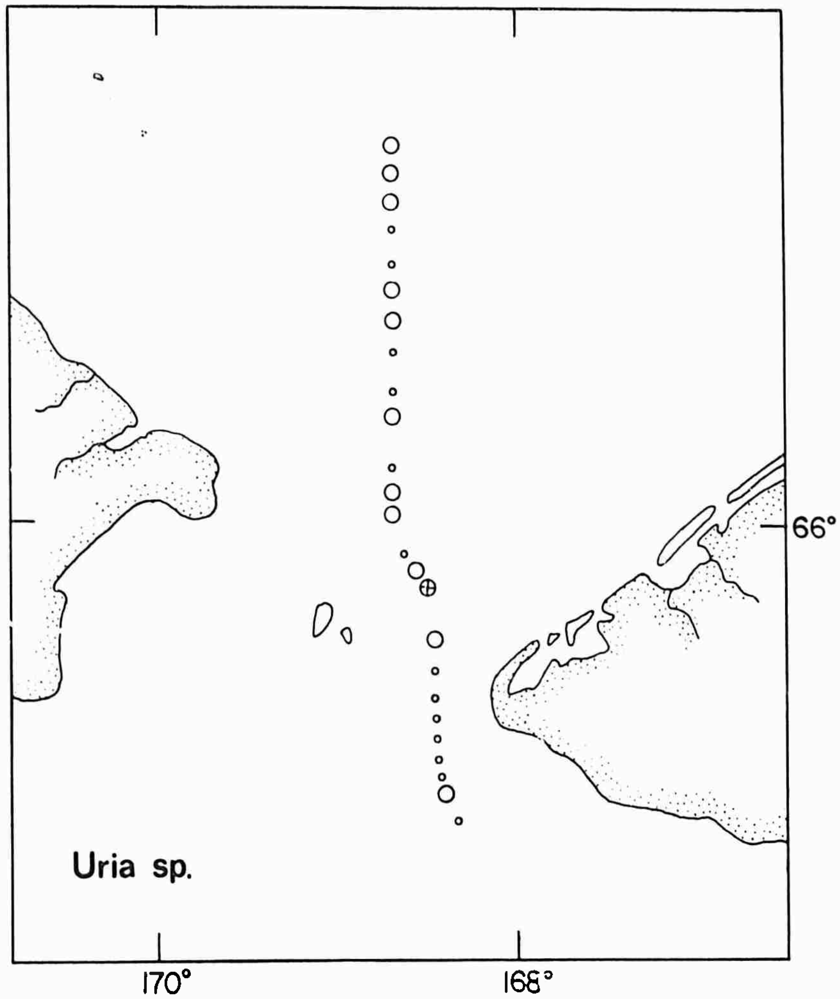

***Figure 28.*—Distribution of murres in Bering Strait, 18 October 1970.**

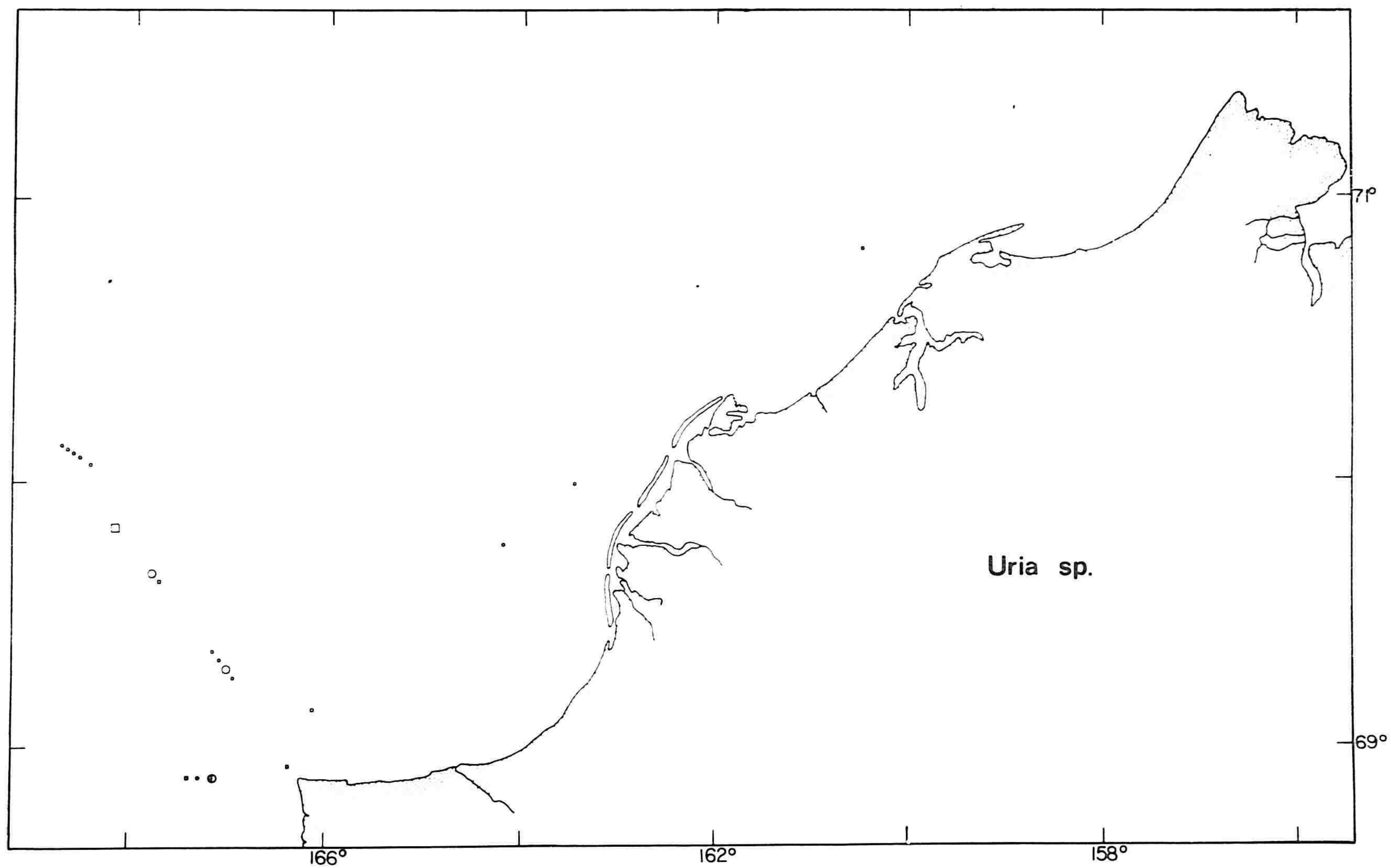

Figure 29.—Distribution of murres from Point Barrow to Cape Lisburne, 22 September–17 October 1970. See also Figure 30.

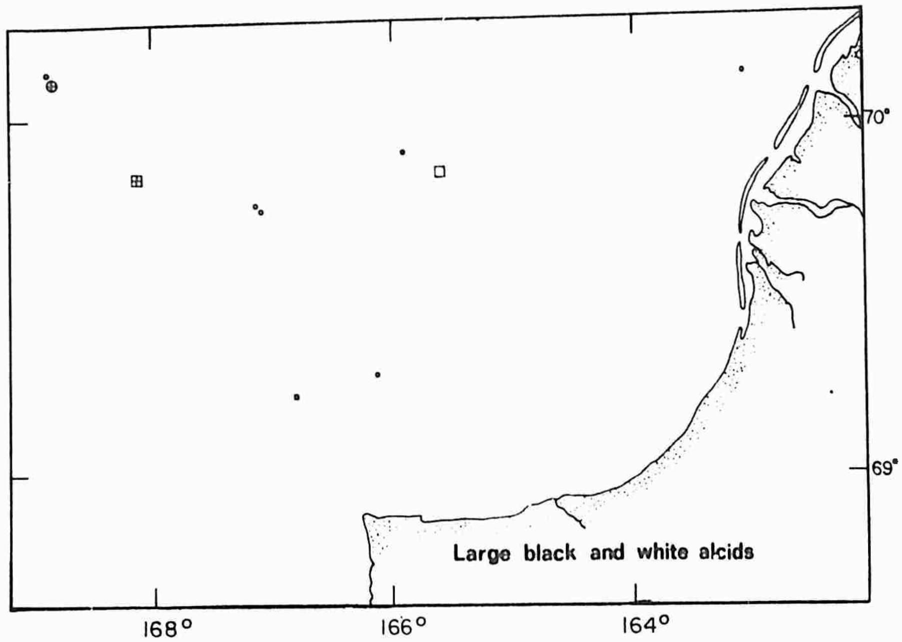

Figure 30.—Distribution of large black and white alcids off Cape Lisburne, 25 September–17 October 1970. See also Figures 29 and 31.

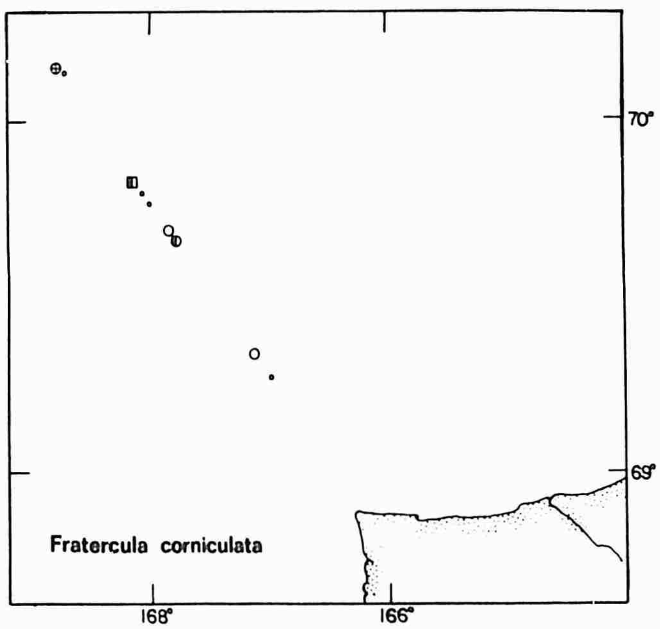

Figure 31.—Distribution of Horned Puffin off Cape Lisburne, 25 September–17 October 1970. See also Figure 30.

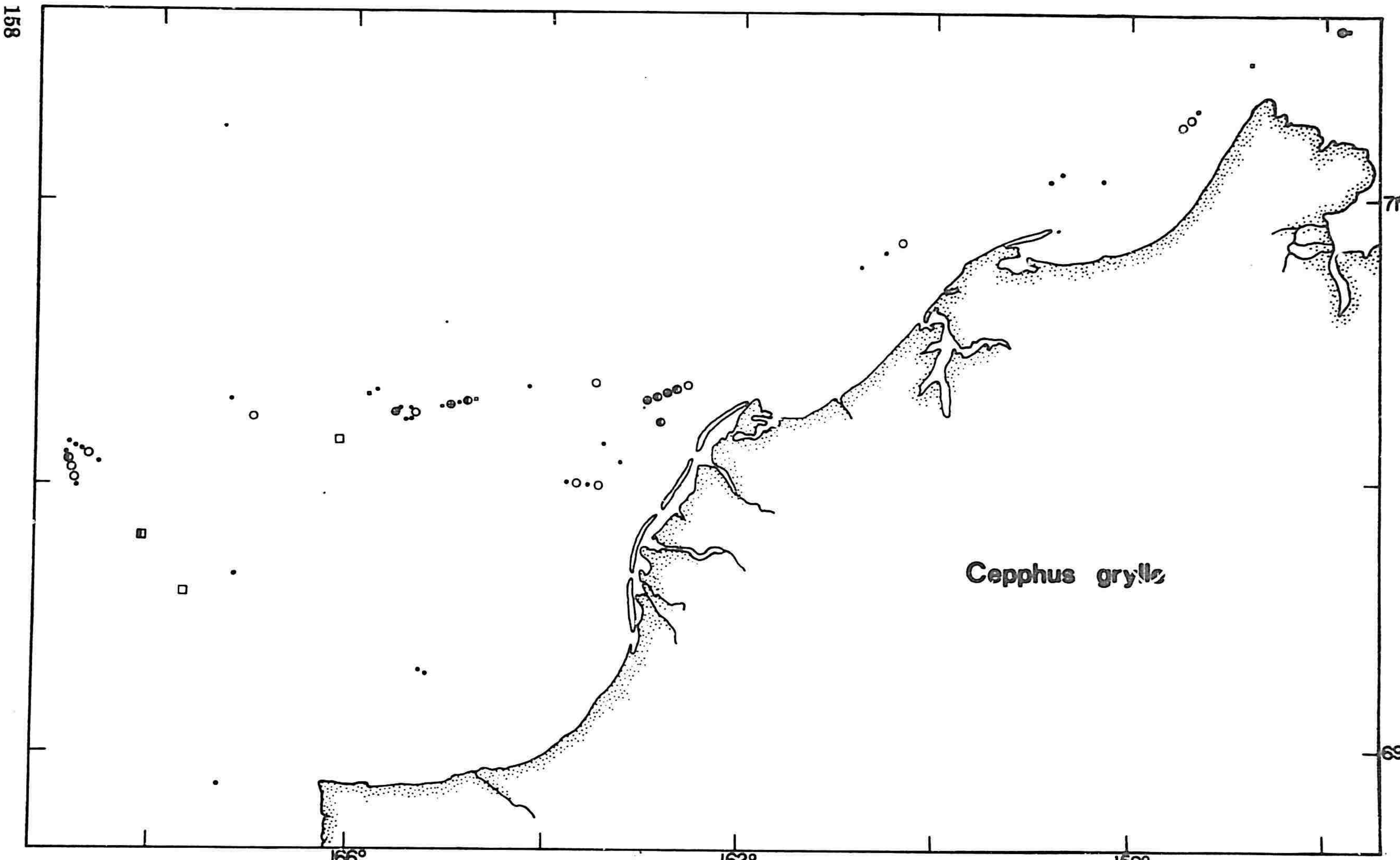

Figure 32.—Distribution of Black Guillemot from Point Barrow to Cape Lisburne, 22 September–17 October.

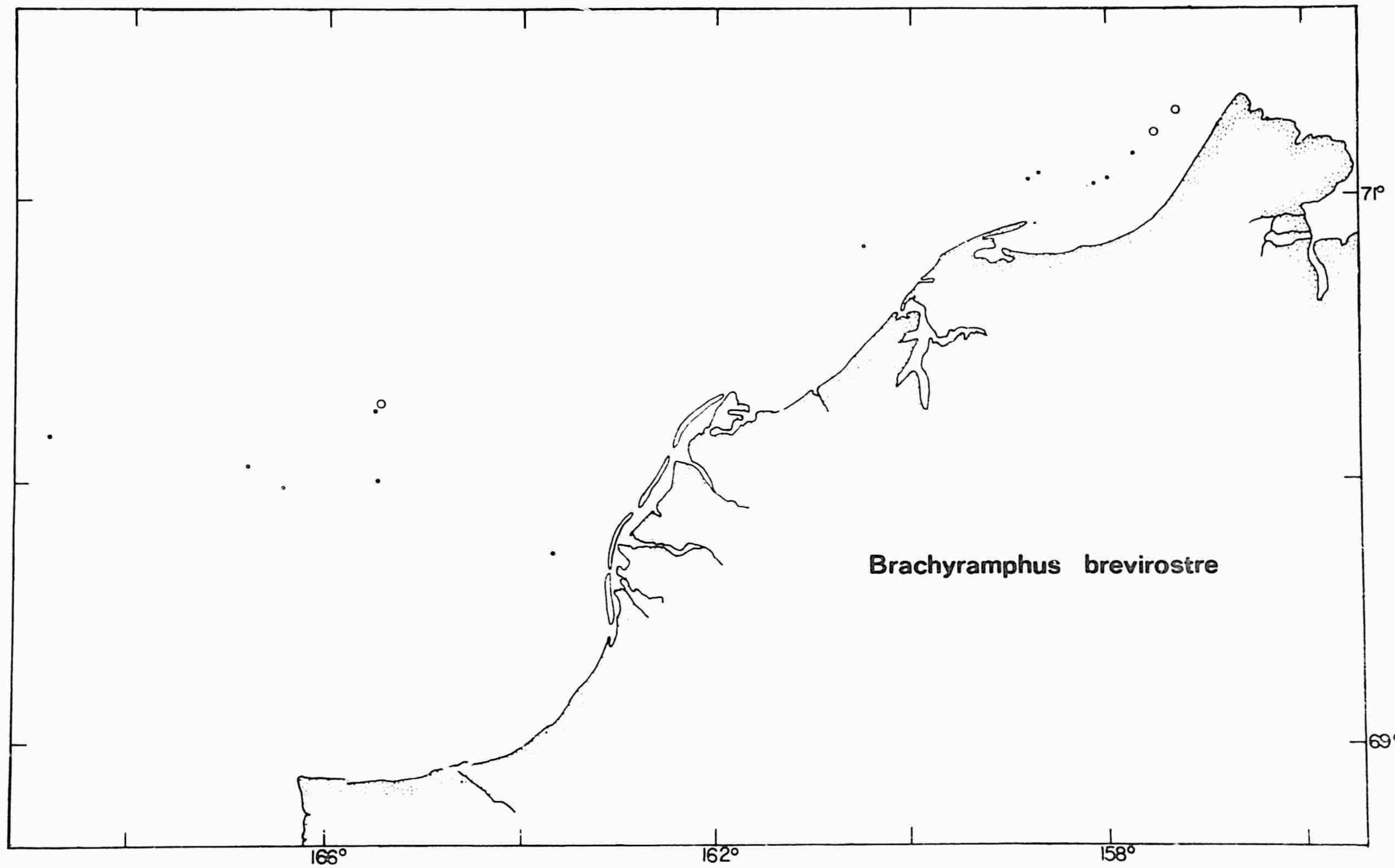

Figure 33.—Distribution of Kittlitz's Murrelet from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

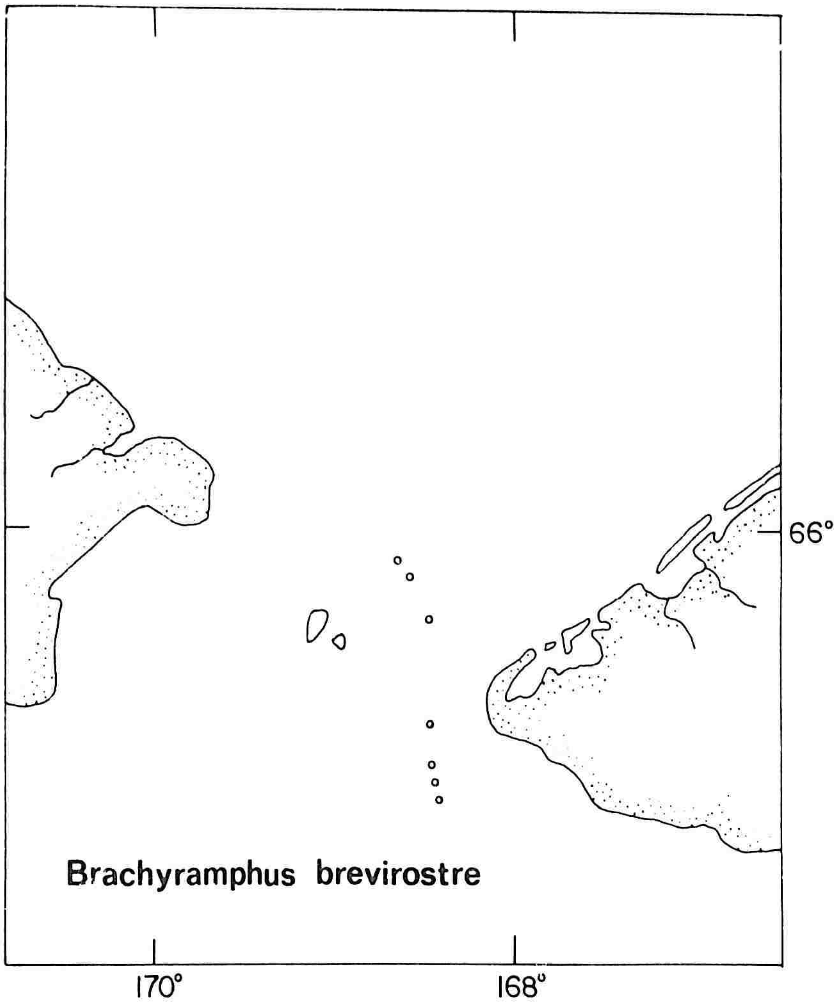

Figure 34.—Distribution of Kittlitz's Murrelet in Bering Strait, 18 October 1970.

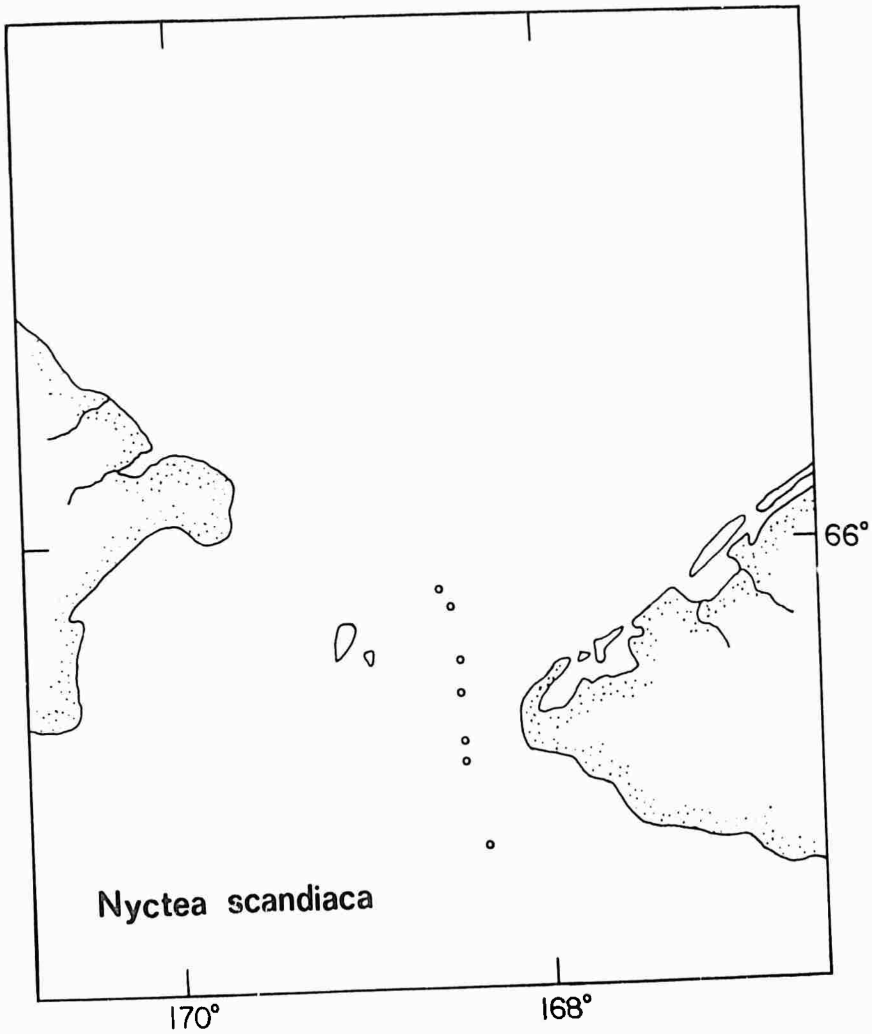

Figure 35.—Distribution of Snowy Owl in Bering Strait, 18 October 1970.

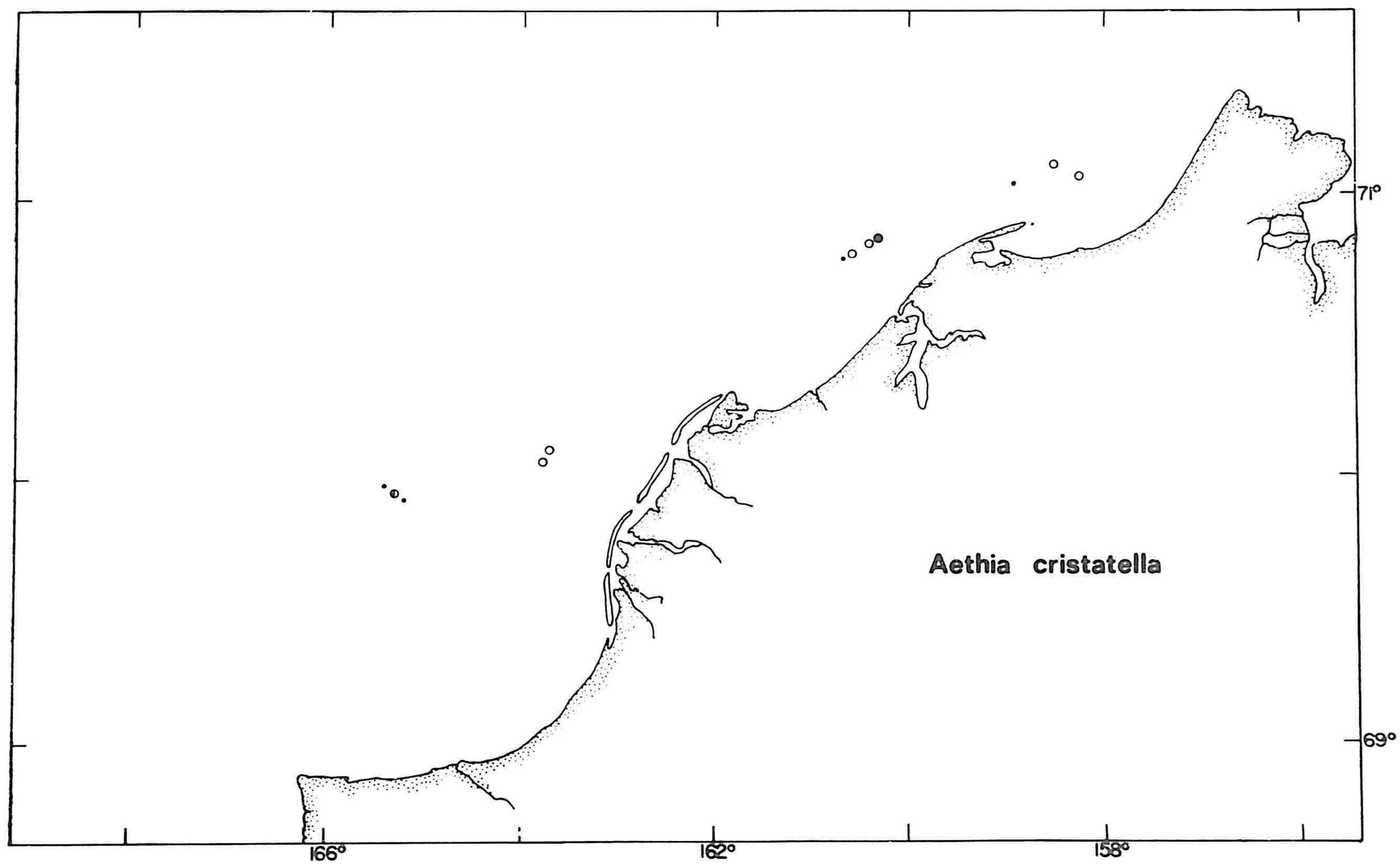

Figure 36.—Distribution of Crested Auklet from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

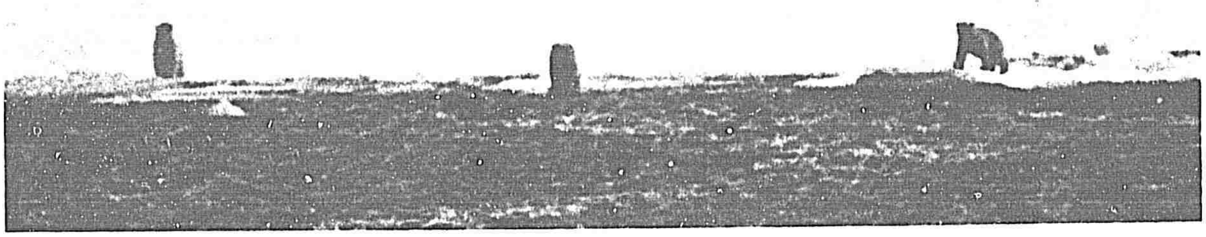

Figure 37.—Three Polar Bears on edge of pack ice, presumably a female and two nearly full-grown cubs.

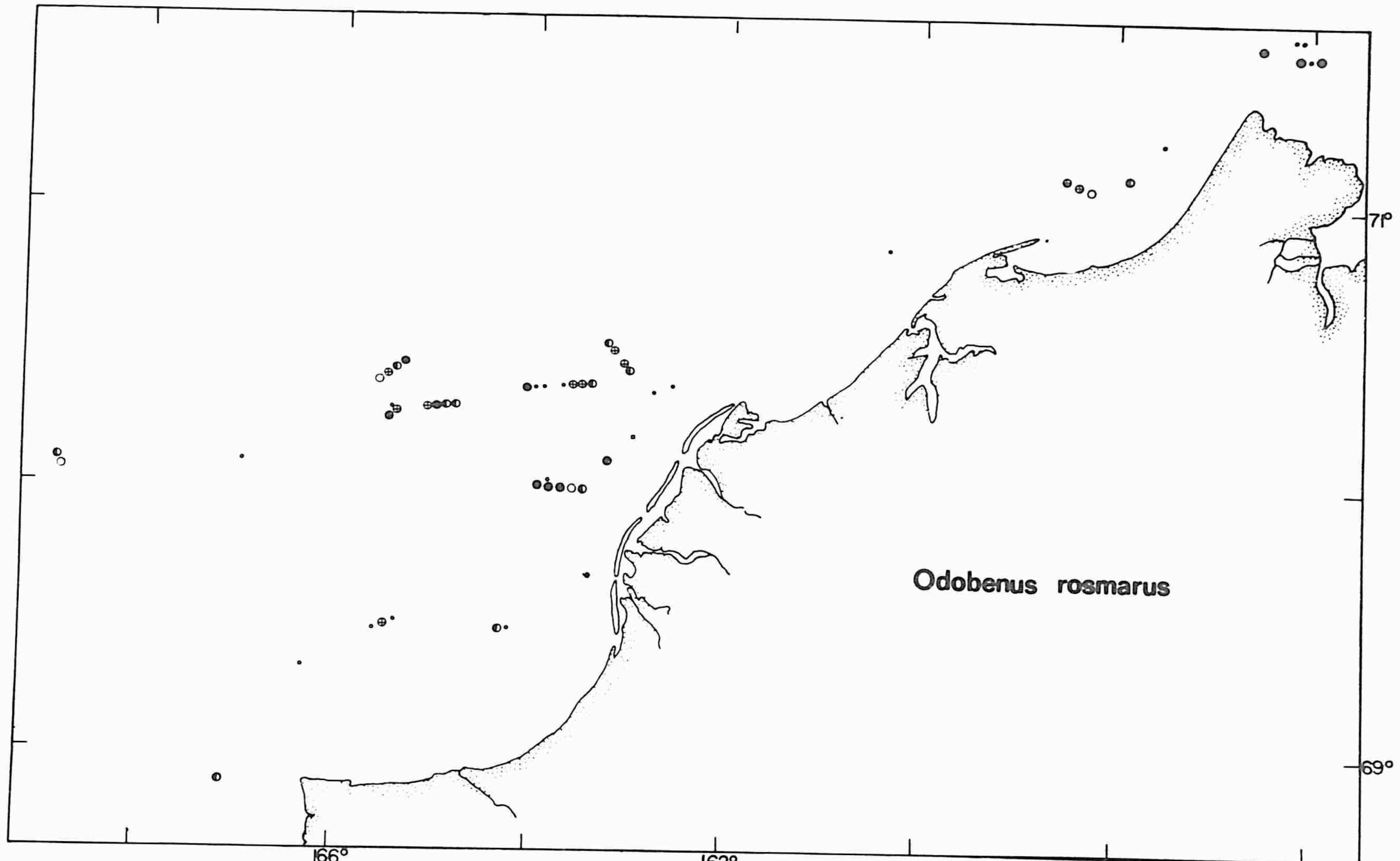

Figure 38.—Distribution of Walrus from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

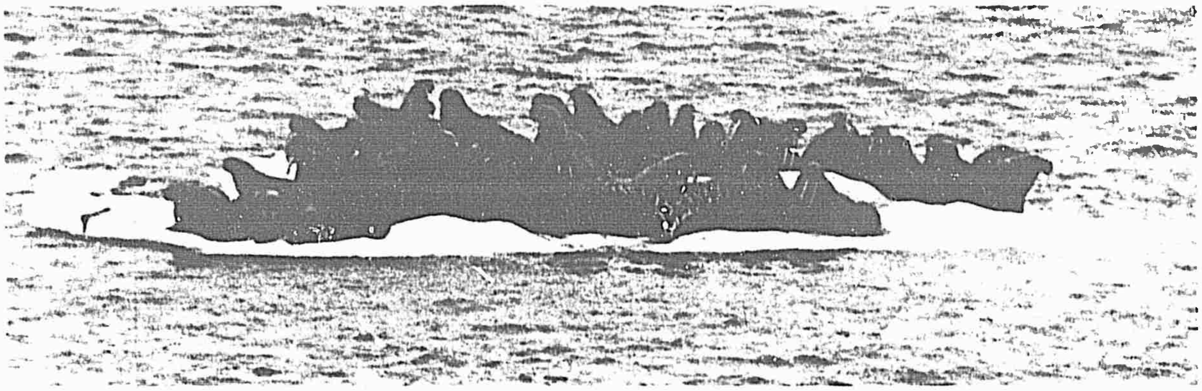

Figure 39.—A pod of at least 57 Walrus on ice cake.

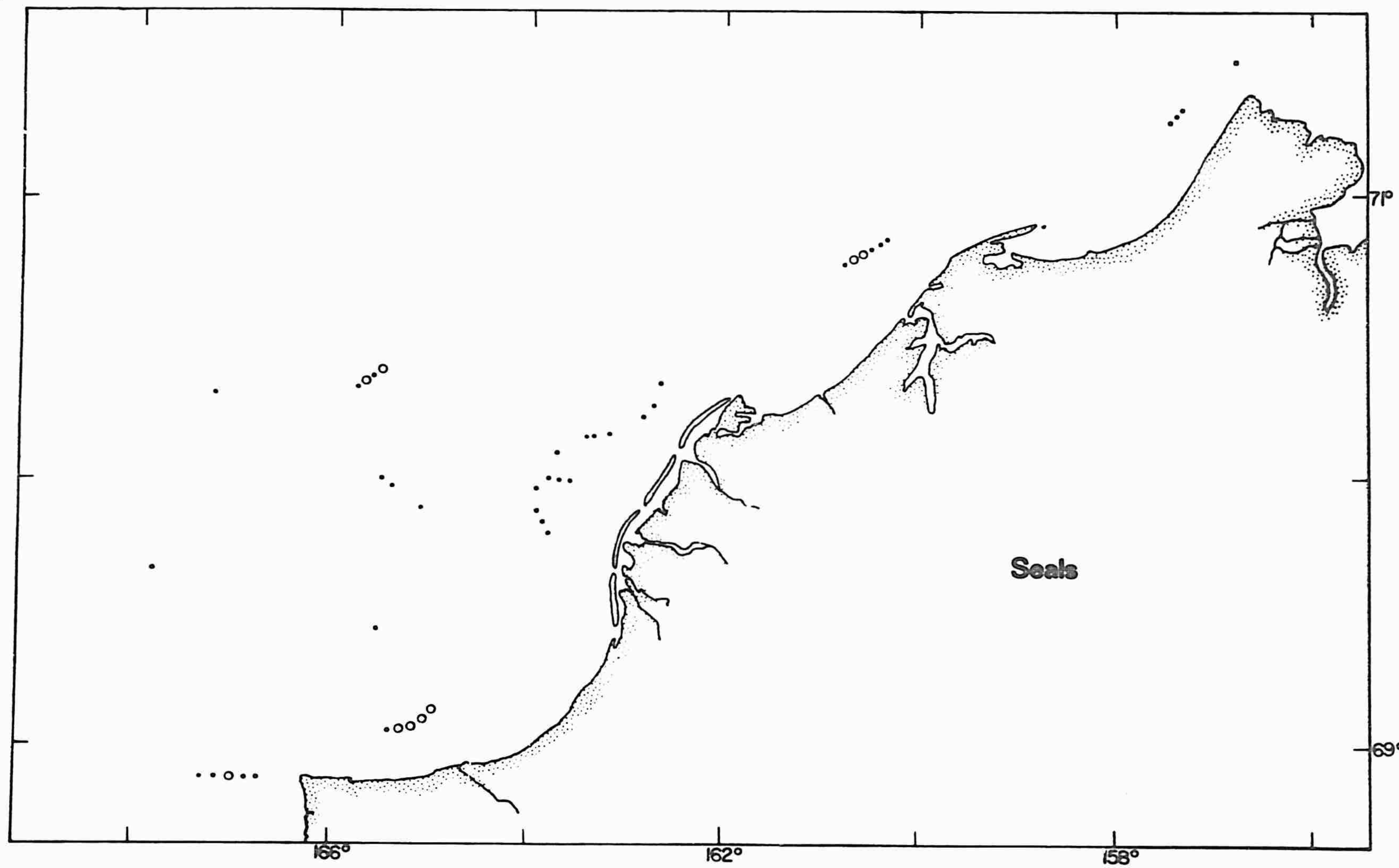

Figure 40.—Distribution of seals from Point Barrow to Cape Lisburne, 22 September–17 October 1970.

Appendix A—Data

Table I.—Environmental Conditions on Transects and Stations.

	Transects	Time (BST)	Stations	Time (BST)
22 September 1970				
			1	1700–1900
		No environmental data collected	(71°34′ N	155°53′ W)
23 September 1970				
	1	0730–0925	1	0925–1000
	2	1000–1100	(71°34′ N	155°53′ W)
	3	1200–1300		
		No environmental data collected		
24 September 1970				
	4	0630–0814	5	0940–1020
	5	0840–0900	6	1135–1155
	6	1020–1135	7	1355–1455
	7	1155–1355		
	8	1800–2000		

Local time	Position N. Lat.	W. Long	Wind Dir.	Vel (kts)	Cloud cover Tenths	Type	Temperature °C Air	Sea surf	Waves Hgt. Ft.	Visibility (miles)
0900	71°08′	157°09′	013	7	10	altost. cirrost.	–4.7	–0.4	--	7
1200	71°05′	158°32′	200	10	10	stcu.	–3.7	0.4	--	7
1500	71°00′	159°09′	182	14	10	stcu.	–2.7	0.5	--	6
1800	70°42′	160°19′	045	4	10	stcu.	–0.15	–0.9	--	7
2100	70°43′	160°57′	080	9	10	stcu.	–0.4	0.2	--	7
25 September 1970										
		9	0735–1035				8	1035–2359		
0600	70°18′	163°07′	070	3	4	stcu.	–0.6	3.9	--	7
0900	69°55′	163°58′	000	0	2	altost.	0.0	4.4	--	7
1200	69°45′	163°33′	230	2	4	cum.	2.1	3.4	01	7
1500	69°45′	163°33′	232	15	9	stcu.	2.7	3.4	02	7
1800	69°45′	163°33′	236	22	10	stcu.	3.2	3.4	03	6
2100	69°45′	163°33′	316	15	10	stcu.	0.1	3.3	03	6
26 September 1970							8	0000–2359		
0000	69°45′	163°33′	357	18	10	stcu.	0.6	3.3	--	6
0300	69°45′	163°33′	330	13	6	stcu.	–1.9	3.4	--	7
0600	69°45′	163°33′	310	14	10	stcu.	–3.1	3.4	--	7
0900	69°45′	163°33′	330	15	10	stcu.	–4.6	3.5	03	7
1200	69°45′	163°33′	320	11	10	stcu.	–4.3	3.5	00	6
1500	69°45′	163°33′	353	9	10	stcu.	–3.7	3.3	03	6
1800	69°45′	163°33′	357	3	10	stcu.	–4.1	3.5	03	6
2100	69°45′	163°33′	313	2	10	stcu.	–3.9	3.4	02	7
27 September 1970										
		10	0850–1110				8	0000–0850		
		11	1130–1450				9	1520–2111		
0000	69°45′	163°33′	294	4	10	stcu.	–3.2	3.4	--	6
0300	69°45′	163°33′	340	13	10	stcu.	–4.0	3.5	--	7
0600	69°45′	163°33′	340	4	10	stcu.	–4.0	3.5	--	7
0900	69°45′	163°33′	300	11	10	stcu.	–4.9	3.5	--	7
1200	69°51′	164°51′	330	8	10	stcu.	–5.8	4.0	01	6
1500	70°09′	166°02′	323	21	10	stcu.	–5.6	2.8	01	6
1800	70°08′	165°58′	340	20	10	stcu.	–6.7	1.7	--	6
2100	70°08′	165°58′	005	5	10	stcu.	–6.9	0.2	--	7
28 September 1970										
		12	1345–1445				11	0730–1215		
							12	1605–1934		
0900	70°19′	165°45′	330	2	10	stcu.	–7.1	–0.2	--	7
1200	70°19′	165°45′	330	3	10	stcu.	–7.2	–0.1	--	7

Local time	Position N. Lat.	W. Long	Wind Dir.	Vel (kts)	Cloud cover Tenths	Type	Temperature °C Air	Sea surf	Waves Hgt. Ft.	Visibility (miles)
1500	70°25′	165°24′	354	20	10	stcu.	–8.3	–0.1	--	7
1800	70°25′	165°24′	313	3	10	stcu.	–8.6	–1.2	--	5
29 September 1970										
		13	0810–1115				15	1415–1749		
		14	1220–1400							
0900	70°17′	165°02′	340	7	10	fog	–7.8	0.0	--	1/8
1200	70°17′	165°09′	330	2	10	altost.	–7.2	1.9	--	7
1500	70°18′	164°41′	311	11	10	stcu.	–6.6	1.1	--	7
1800	70°18′	164°41′	337	12	10	stcu.	–6.7	0.5	--	7
30 September 1970										
		15	1115–1400				18	0740–1055		
							19	1435–1640		
0900	70°21′	164°09′	290	8	10	altocu.	–7.2	1.6	--	7
1200	70°21′	164°09′	310	18	10	altost.	–6.6	1.7	--	7
1500	70°22′	163°16′	310	5	9	altocu.	–9.8	1.7	--	7
1 October 1970										
		16	1240–1445				20	0735–1240		
							21	1445–1745		
0600	70°28′	163°07′	290	7	10	stcu.	–9.5	–1.2	--	7
0900	70°26′	162°53′	310	4	10	nmbst.	–9.3	0.2	--	7
1200	70°26′	162°53′	310	3	10	nmbst.	–8.4	0.4	--	7
1500	70°35′	163°16′	296	4	10	stcu.	–6.9	–1.1	--	7
1800	70°35′	163°16′	314	4	6	altocu.	–10.0	–1.2	--	7
2 October 1970										
		17	0840–1050				23	1050–1450		
		18	1520–1700				24	1720–1845		
		19	1910–1940							
0900	70°18′	163°18′	290	2	10	stcu.	–8.4	–0.7	--	7
1200	70°23′	162°24′	270	3	10	stcu. altocu.	–7.7	–1.0	--	7
1500	70°23′	162°24′	287	5	2	stcu. altocu.	–9.1	–1.1	--	7
1800	70°09′	162°52′	334	2	4	stcu.	–7.6	0.2	--	7
3 October 1970										
		20	0750–0945							
0900	70°12′	162°59′	000	0	10					
4 October 1970						fog	9.4	–1.1	--	1/30
		21	1300–1505				28	0820–1240		
							29	1505-2015		
0900	69°59′	163°14′	120	4	10	fog	–6.2	1.1	--	1/16
1200	69°59′	163°14′	110	3	8	altcu.	–6.6	1.2	--	5
1500	70°05′	164°02′	000	0	10	stcu.	–0.1	0.2	--	4
1800	70°05′	164°02′	120	8	10	stcu.	–2.6	2.2	--	4
2100	70°05′	164°02′	104	11	10	stcu.	–2.3	2.2	--	1/11
5 October 1970							31	800-1955		
0900	69°44′	163°33′	060	4	6	altcu. stcu.	–3.9	0.9	3	5
1200	69°44′	163°33′	100	10	0	clear	–5.1	0.8	--	7
1500	69°44′	163°33′	079	12	0	clear	–3.9	1.3	--	7
1800	69°44′	163°33′	079	19	0	clear	–3.9	1.2	--	6
6 October 1970										
		22	1125–1305				34	0840–1120		
		23	1600–1725							
0900	69°56′	164°54′	050	26	10	stcu.	–6.0	2.8	--	7
1200	69°58′	165°12′	060	24	10	stcu.	–5.3	3.3	5	6
1500	70°01′	165°34′	044	26	10	stcu.	–5.8	2.7	6	6
1800	70°07′	166°13′	040	27	9	stcu.	–9.2	2.3	7	3
7 October 1970										
		24	1230–1310				40	1345–1640		
		25	1730–1850							

Local time	Position N. Lat.	W. Long	Wind Dir.	Vel (kts)	Cloud cover Tenths	Type	Temperature °C Air	Sea surf	Waves Hgt. Ft.	Visibility (miles)
1200	70°08′	167°07′	050	35	10	stcu.	−7.2	3.0	--	4
1500	70°18′	166°57′	030	27	9	stcu. altcu.	−9.7	0.7	--	7
1800	70°19′	167°10′	054	17	9	stcu. altcu.	−9.6	−0.9	--	7
8 October 1970										
		26	1010–1255				43	0755–1010		
		27	1710–1901				44	1325–1705		
0900	70°09′	168°21′	030	20	9	stcu.	−8.9	1.6	2	7
1200	70°00′	168°38′	020	15	4	cirrus	−9.0	2.0	--	7
1500	70°12′	169°04′	016	8	2	stcu.	−10.4	0.5	--	7
1800	70°05′	168°53′	020	18	1	altocu.	−11.6	0.5	--	7
9 October 1970										
		28	1345–1525				49	0815–1325		
							50	1530–2015		
0900	69°47′	168°05′	070	4	10	altcu.	−7.2	3.1	--	7
1200	69°47′	168°05′	100	3	10	altst.	−6.0	3.2	--	7
1500	69°46′	167°59′	097	8	10	stcu.	−5.7	2.9	--	7
1800	69°37′	167°45′	092	9	10	stcu.	−5.0	3.1	--	7
2100	69°38′	167°44′	104	21	10	stcu.	−4.8	2.9	2	4
10 October 1970										
		29	1215–1345				54	0800–1150		
							55	1347–2205		
0900	69°24′	167°15′	030	10	10	stratus	−6.9	2.8	--	5
1200	69°24′	167°15′	010	10	10	stratus	−6.9	2.8	--	5
1500	69°13′	166°52′	330	10	10	stratus	−7.2	2.6	3	4
1800	69°13′	166°52′	266	3	10	stratus	−7.1	1.9	3	4
2100	69°13′	166°52′	310	11	10	stratus	−7.7	1.8	3	5
11 October 1970										
		30	1110–1200				59	0800–1100		
							60	1200–1920		
0900	69°04′	167°34′	050	22	10	stratus	−7.7	1.8	5	6
1200	68°58′	166°25′	050	22	8	stcu.	−7.2	1.5	4	7
1500	68°57′	166°25′	312	32	8	stcu.	−7.8	1.0	7	7
1800	68°57′	166°25′	283	30	9	stcu.	−8.2	1.1	7	5
12 October 1970										
		31	1410–1600				62	0832–1038		
0900	69°06′	166°03′	060	25	10	stratus	−12.2	0.6	7	1
1200	69°13′	165°52′	030	33	10	stratus	−11.9	0.5	5	1
1500	69°19′	165°06′	065	16	10	stratus	−10.4	0.5	7	1
13 October 1970										
		32	0905–1030							
		33	1330–1845							
0900	69°39′	167°13′	040	23	10	stratus	−12.4	2.2	5	½
1200	69°51′	167°23′	030	25	10	stratus	−12.7	2.1	2	½
1500	69°41′	166°36′	004	21	8	stratus	−11.4	1.9	3	5
1800	69°32′	166°55′	032	26	10	stratus	−11.7	1.6	3	5
14 October 1970										
		34	0855–1010							
		35	1240–1530							
0900	69°21′	165°26′	050	25	10	stratus	−11.0	−0.6	4	6
1200	69°18′	165°14′	050	15	10	stratus	−12.1	−0.8	4	5
1500	69°33′	164°31′	104	18	10	stratus	−12.2	−1.0	3	1
15 October 1970										
		36	0850–0950				78	0950–1155		
		37	1230–1620							
0900	69°32′	165°22′	070	16	10	stratus	−11.7	−1.1	1	1
1200	69°27′	165°40′	070	20	10	stratus	−11.4	−0.8	2	6
1500	69°26′	164°41′	030	12	10	stratus	−11.6	−0.6	3	7
1800	69°28′	164°09′	074	15	4	stratus	−13.1	−1.8	--	4

Local time	Position N. Lat.	W. Long	Wind Dir.	Vel (kts)	Cloud cover Tenths	Type	Temperature °C Air	Sea surf	Waves Hgt. Ft.	Visibility (miles)
16 October 1970										
		38	1035–1135				86	1135–1355		
		39	1400–1530							
		40	1800–1900							
0900	69°13′	164°49′	040	12	10	stratus	–16.6	–1.7	--	7
1200	69°05′	165°05′	080	5	9	stratus	–15.5	–1.7	--	7
1500	69°06′	165°25′	090	13	10	stratus	–13.2	–1.7	--	7
1800	69°04′	165°36′	080	4	10	stratus	–12.8	–1.7	--	6
2100	69°02′	166°46′	123	7	6	stratus	–12.5	–1.8	--	7
17 October 1970										
		41	1230–1415				90	0800–1220		
							91	1415–1740		
0900	68°55′	166°43′	140	5	5	stcu.	–8.3	–1.1	--	7
1200	68°54′	166°43′	170	4	5	cum.	–4.7	–1.2	--	7
1500	68°54′	167°25′	040	7	10	stratus	–4.1	–1.1	--	7
1800	68°55′	167°32′	167	13	10	stratus	–3.5	–0.9	--	5
18 October 1970										
		42		0845–1900						
0600	67°25′	168°30′	240	2	10	stcu.	–1.7	1.2	1	7
0900	66°48′	168°30′	340	8	8	stcu.	–1.7	2.4	1	7
1200	66°17′	168°30′	340	10	9	stcu.	–1.4	2.4	1	7
1500	65°55′	168°27′	004	14	10	stcu.	–1.3	2.2	1	5
1800	65°23′	168°24′	340	16	10	stcu.	–1.1	2.2	1	7
2100	65°06′	167°47′	358	16	10	stcu.	–0.8	2.2	1	7

Table II.—Bird Specimens Collected in the Chukchi Sea.

Species	Stations 7	Pt. Lay 26 Sep.	8	9	11	15	19	21	23	44	49	50	86	91
Clangula hyemalis		1 im												
Somateria mollissima													1 im	1 im
Larus hyperboreus			2 ad			2 im	1 im		1 ad 1 im					
Larus argentatus						1 im								
Pagophila eburnea	3 ad			3 ad 4 im	2 im		1 ad			1 ad				
Rissa tridactyla	1 im								1 im		1 im	1 ad		
Rhodostethia rosea	7 ad 2 im			6 ad 2 im			1 im	1 im	2 ad 5 im			1 ad		
Uria aalge												1 ad		
Cepphus grylle						1 ad					1 im	1 im		
Plectrophenax nivalis		5 ad 1 im												

Notes: Station dates and coordinates are given in Table I; ad=adult, im=immature, including both first- and second-year birds.

Table III.—Flocking of Gulls on Transects and Stations.

Observations during 208 20-minute intervals on transects

Species	Intervals with gulls seen	Mean no. gulls/interval	Single gull intervals
Larus hyperboreus	74	3.3	32
Pagophila eburnea	61	4.3	28
Rissa tridactyla	44	2.8	22
Rhodostethia rosea	70	18.8	7

Observations at 28 stations

	Stations with gulls seen	Mean no. gulls/station
Larus hyperboreus	22	18.7
Pagophila eburnea	19	14.3
Rissa tridactyla	12	5.9
Rhodostethia rosea	20	22.6

Table IV.—Ice Affinities of Gulls.

Species	Ice		Open water		X^2	Significant at 99.5 percent
	Present	Absent	Present	Absent		
Transects:						
Larus hyperboreus	48	88	11	39	2.98	No
Pagophila eburnea	55	81	2	48	22.8	Yes
Rissa tridactyla	21	115	22	28	16.77	Yes
Rhodostethia rosea	50	86	7	43	8.9	Yes
Stations:						
Larus hyperboreus	15	2	7	8	1.38	No
Pagophila eburnea	13	4	6	4	8.1	Yes
Rissa tridactyla	2	15	9	1	15.9	Yes
Rhodostethia rosea	12	5	7	3	.001	No

Table V.—Stomach Contents of Birds Collected in Chukchi Sea.

Species	Stomachs Examined	Stomach contents					
		Arctic Cod	Crustaceans	Tunicates, Molluscs	Ship refuse	Plant material	Empty
Clangula hyemalis	1	0	0	0	0	0	1 (100%)
Somateria mollissima	2	0	0	1 (50%)	0	1 (50%)	1 (50%)
Larus hyperboreus	6	5 (83%)	1 (17%)	2 (34%)	1 (17%)	0	0
Larus argentatus	1	1 (100%)	0	0	0	0	0
Pagophila eburnea	14	12 (86%)	1 (7%)	1 (7%)	1 (7%)	2 (14%)	1 (7%)
Rissa tridactyla	4	4 (100%)	0	0	0	0	0
Rhodostethia rosea	24	17 (71%)	13 (54%)	0	0	0	0
Uria aalge	1	1 (100%)	1 (100%)	0	0	0	0
Cepphus grylle	3	3 (100%)	1 (33%)	0	0	0	0

Table VI.—Methods of Feeding of Chukchi Seabirds in the Fall.

Species	Food	Method of capture	Depth
Loons	Fish	Surface diving	Surface, midwater
Ducks	Molluscs, crustaceans	Surface diving	Bottom
Phalaropes	Zooplankton	Surface feeding	Surface
Jaegers	Mostly fish	Piracy from gulls, alcids	In air, surface
Glaucous Gull	Fish, crustaceans, refuse	Surface feeding	Surface
Ivory Gull	Fish, refuse	Contact dipping	Surface
Kittiwake	Fish	Plunge to surface	Surface
Ross' Gull	Crustaceans, fish	Hovering, plunge to surface, surface feeding	Surface
Large alcids	Fish, crustaceans	Surface diving	Surface, midwater
Small alcids	Crustaceans	Surface diving	Surface, midwater

Geological, Biological, and Chemical Oceanography of the Eastern Central Chukchi Sea[1]

A. S. NAIDU [2] and G. D. SHARMA [2]

GEOGRAPHIC AND GEOLOGIC SETTINGS

The nearshore environment of the eastern central Chukchi Sea lies west of northwest Alaska (fig. 1). East of Point Barrow this sea merges imperceptibly into the western Beaufort Sea. The coastline between Point Barrow and Point Lay is very slightly curved, but further south to Cape Lisburne the coast is distinctly embayed. Between Icy Cape and Point Lay a barrier-spit-lagoon-delta complex characterizes the coastline.

The oceanography of the Chukchi Sea off Alaska's northern coast has not been investigated as thoroughly as that portion between the Bering Strait and Cape Lisburne in the southeastern Chukchi Sea. From a few soundings made by Moore (1964) and Creager and McManus (1965) it is suggested that the offshore area between Icy Cape and Point Lay is shallow (<25 m), very flat and featureless. Contrary to this the topography off Point Hope is relatively steep and is characterized by the presence of a submarine valley (Creager and McManus, 1966). In the area we investigated there is a net northward movement of currents over the year (Aagaard and Coachman, 1964), although presence of a local clockwise gyre has been indicated off Cape Lisburne by Fleming and Heggarty (1966).

The eastern central Chukchi Sea is covered with ice almost 8 months of the year. The climate over this sea and the hinterland is dominated by long severe winters and short cool summers, with a mean annual temperature around 20° F. The average rainfall of 10 inches is comparable to that in arid and semiarid regions. The northwestern coast of Alaska is generally windy and storms are not uncommon.

The drainage basin adjacent to the eastern central Chukchi Sea coast consists of the Coastal Plain and the Foothill Provinces (Payne *et al.*, 1951); the latter pass in the southeast into the Brooks Range. Cape Lisburne consists of a limestone promontory. The geology of the southern hinterland of the eastern central Chukchi Sea, extensively studied by Smiley (1969a and 1969b), is composed of the predominantly marine Kukpowruk and nonmarine Corwin Formations of Early Albian to possibly Cenomanian age. These rock types are chiefly conglomerates, graywackes, sandstones, shales and limestones, with coal beds confined to the nonmarine formations. In far northwestern Alaska the coastal plains are overlain with Quaternary glacial and glacio-fluvial sediments, alluvium and beach deposits.

METHODS AND MATERIALS

The geological sampling yielded a suite of 107 sediment samples from the nearshore marine environment of the eastern central Chukchi Sea (fig. 1) Of the total samples collected, 73 were obtained with a Van Veen and/or Shipek grab sampler, 13 were short cores obtained with a gravity corer, one was a long piston core and 15 were handpicked from the beach surface. The beach samples were taken from a few transects across the barrier in the vicinity of Point Lay to study the nature of arctic barrier beach deposits coincident with the beginning of ice push onto the beaches.

To minimize metal contamination, the 13 gravity core samples were collected in plastic core liners with no metal core barrel or core catcher. The gravity corer was dropped only on stations which had relatively muddy bot-

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toms. The nature of the sea bottom was determined by first taking a grab sample at every station. Aboard the ship immediately after collection, the gravity core sediment samples were extruded from the core liner with a core pusher that also introduced the least metal contamination. After extrusion, the surficial portion around the sediment core was carefully scraped out using a teflon-coated spatula. This step was introduced to minimize the inclusion of any soupy sediment that might have run down the length of the core from the top during retrieval of the corer. Then the sediment core was cut into two longitudinal halves, one of which was cut into a number of convenient small transverse sections. Almost immediately after this, the pH and temperature of these wet sediments were measured with a Coleman, Model 37A, portable pH-Eh meter and a glass thermometer, respectively. The interstitial fluids of these sediment sections were separately squeezed out into polyethylene bottles using squeezers described by Reeburgh (1967). In order to avoid chemical precipitation of some hydroxides and biochemical reactions the expressed interstitial fluids were acidified with 0.1 ml of conc. HCl and stored frozen. After it was examined and photographed, the second half of each core was cut into a number of transverse sections aboard the ship and stored at freezing temperature in polyethylene bags and bottles for further laboratory analysis.

Prior to storing, the inorganic P concentrations in the sediment interstitial fluids were determined colorimetrically aboard the ship. At the Institute laboratory the K, Na, Ca, Mg, Fe and Mn concentrations in 40 of these samples were analyzed in a Perkin-Elmer, Model 290, atomic absorption spectrophotometer.

Forty water samples were collected from 14 stations with Niskin bottles at various depths. Aboard the ship 500 ml of these water samples were filtered through 0.45 μ millipore filter papers in order to separate suspended particulate matter.

Approximately 1-gallon unfiltered water samples were collected at a number of depths from two stations (table 1). These samples were frozen for trace transition metal analyses at the Institute laboratory. The concentrations of Cu, Co, Ni, Fe, Zn, and Pb were determined with an atomic absorption spectrophotometer, following the APDC/MIBK extraction technique of Brooks *et al.* (1967). The water samples were not filtered prior to chemical analysis because previous experience had indicated potential contamination problems from filtering, and because the particulate content of the samples was exceedingly low. Thus, the present analysis represents only total extractable ions (written communication, Mr. M. Lee, Institute of Marine Science, University of Alaska).

Benthic organisms having a size between 2.8 mm and 0.99 mm were collected from 16 stations by wet-sieving a measured volume of bottom sediments collected by the Van Veen grab sampler. Organisms thus separated were preserved in 10 percent formalin solution, buffered with sodium acetate, for identification and cataloging in the laboratory.

The gravel-sand-silt-clay contents of the core sections and detailed size distributions of the barrier beach sediments were determined by following the method of Krumbein and Pettijohn (1938). Conventional grain size parameters were calculated based on the formulae of Folk and Ward (1957).

A set of 24 sediment samples was selected for clay mineral analysis from the inshore shelf area of the Chukchi Sea adjacent to Alaska. Two of them were obtained from Dr. J. S. Creager, University of Washington, and the remainder, including two from south of the Bering Strait, were collected from the GLACIER on WEBSEC–70. In the less-than-2 μ fraction of the bottom sediment samples and in two samples of suspended sediments the clay mineral assemblage was determined by X-ray diffraction technique. Details of the techniques and steps adopted for the separation of the less than 2 μ fraction, the X-ray analysis, and the method of quantifying the clay minerals were similar to those presented by Naidu *et al.* (1971).

RESULTS

Grain-Size Analysis

Vertical variations of the percentage composition of gravel-sand-silt-clay in the cores are presented in table I (appendix A) and illustrated in figure 2. In the majority of the cores there is a general coarsening in the sedi-

ment texture from the top to the bottom, and every core sample contains small amounts of gravel and bioclastic material. The longitudinal sections of the cores which were examined aboard the ship showed a sharp demarcation in color and rigidity between 5 and 10 cm from the top. The top 5 to 10 cm portions of all cores were light olive-green and relatively soft, whereas all the sediments below 10 cm were dark olive-green with irregular black streaks and patches and were tough. Some of the lower portions gave out an odor of H_2S. On closer scrutiny it was noted that in almost all cases decomposing worms were surrounded by large black patches. Presumably, the sharp demarcation in the sediment core color is related to abrupt vertical changes in the oxidation-reduction potentials along the core, and the black patches represent some stage of hydrotroilite precipitation. The oxidizing nature of the core tops seems to be substantiated by the fact that the habitation of marine macrobenthic fauna was confined to the relatively lighter colored top portions.

The results of the grain-size distribution of the Point Lay barrier beach deposits are graphically represented in figure 3, and the grain-size parameters are given in table II (appendix A). Generally speaking, the analysed sediments consisted of well-rounded, moderately well to very poorly sorted sandy gravels, with distinct bi- to polymodal distributions. The mean size ranged from fine to coarse gravel. These sediments have size distributions which ranged from nearly symmetrical to very coarsely skewed and mesokurtic to leptokurtic. Texturally, there is a great similarity between the sediments of the Point Lay barrier beach and the sediments collected from the barrier beaches around the Colville Delta-Prudhoe Bay complex. The latter suite of samples was analysed in a separate study funded by the E.P.A. and the N.O.A.A.-Sea Grant (Naidu *et al.*, 1970). It is of interest to note that every one of the barrier beach samples contained several gravel-size anthracitic coal pieces.

Clay Mineral Analysis

The types and abundance of clay minerals in the less-than-2 μ fractions of the sediment samples are presented in table III (appendix A), and their distributions are illustrated in figures 4, 5, 6, and 7. In all samples illite is the predominant clay mineral, with weighted peak area (Biscaye, 1965) ranging from 50.0 to 63.3 percent. The next two minerals in the order of abundance are chlorite and kaolinite, respectively. Smectite eitner occurs in traces (less than 1 percent) or in small amounts (less than 10 percent).

The patterns of distribution of clay minerals (figs. 4, 5, 6, and 7) should be considered to be tentative because they are based on a limited number of sample analyses. However, some very broad generalizations can be made from the data obtained. It is of interest to note that smectite occurs either in traces or is absent in the nearshore environment. This is specially true north of Point Lay. Any definite pattern of distribution of kaolinite and illite, if present, is not apparent at this stage of the study. There seems to be, however, a marked concentration of chlorite in the inshore shelf environment and off the embayed region between Point Lay and Cape Lisburne, a region, as mentioned earlier, suspected to be the site of a gyre (Fleming and Heggarty, 1966).

Comparison of the clay mineral assemblages of the Beaufort Sea (Naidu *et al.*, 1971) and eastern central Chukchi Sea sediments brings out some interesting differences between the two. Although sediments from both the seas contain the same clay mineral assemblages, some dissimilarities in the proportions of the different minerals in the two regions are apparent. For example, the kaolinite/chlorite ratios in the eastern central Chukchi Sea are relatively lower (avg. 0.4) than those in the Beaufort Sea (avg. 0.7). However, the chlorite/illite ratios in the Chukchi Sea are relatively higher (avg. 0.6) than those in the Beaufort Sea (avg. 0.4).

Geochemistry of Sediment Interstitial Waters

The concentrations of various ions in the interstitial waters from cores are presented in table I (appendix A) and figures 8 and 9. The cationic concentrations vary from horizon to horizon within individual cores and also between cores. The relative concentrations of ions of the interstitial waters are similar to but slightly higher than normal sea water. Generally, the total concentration of the several ions increases with depth in the core.

The concentrations of Mg^{++}, Ca^{++}, and K^{+}, in interstitial waters are given in relation to Na^{+} to eliminate the effects of evaporation which may give relatively higher absolute measured values. From Figures 8 and 9 it is apparent that Na^{+} and K^{+} generally increase with depth while Mg^{++} and Ca^{++} decrease with depth. Among the trace elements analysed, Mn was found enriched in the top sections of the cores while iron varies irregularly throughout the section.

The influence of texture of sediments on the Na^{+} concentration is apparent. Increased percentage of clay in the cores invariably depressed the Na^{+} concentration.

Variations in temperature and pH of sediments are presented in figures 8 and 9. The pH varied within a narrow range; however, the temperatures of sediments varied significantly. These measurements should be considered as approximations rather than the true values in view of the fact that during retrieval changes in temperature and pressure were unavoidable. The decrease in hydrostatic pressure will inevitably lead to escape of carbon dioxide and an increase in pH. Exposure to air will similarly result in rise or fall of sediment temperature causing an increase or decrease in pH.

Trace-metal Analysis of Sea Water

Table 1 gives the concentrations of Cu, Co, Ni, Fe, Zn, and Pb in six samples of water collected at two stations. The concentrations of Cu (avg. 7.2 ppb) and Co (avg. 0.7 ppb) in eastern central Chukchi Sea waters were slightly higher than the average concentrations of Cu (avg. 3 ppb) and Co (avg. 0.1 ppb) cited for the world ocean waters (Goldberg, 1965). Possibly this slight enrichment in Cu and Co in the nearshore waters of the Chukchi Sea is caused by the local introduction from the adjacent hinterland which is rich in ore deposits of these two metals. The concentrations of Ni (avg. 1.470 ppb), Fe (avg. 5.498 ppb) and Zn (avg. 3.528 ppb) in the eastern central Chukchi Sea water are relatively lower than those generally observed in sea water. Within the area investigated no systematic vertical variations were observed in the concentrations of any of the six metals analyzed.

Table 1.—Concentrations of some trace transition metals in the waters of the eastern central Chukchi Sea. All values are expressed as ppb.

St. No.	Water depth (m)	Cu	Co	Ni	Fe	Zn	Pb
8	0	9.0	0.4	1.6	1.5	4.2	Trace
8	6	4.9	0.8	1.3	6.5	4.0	Trace
8	12	7.8	0.6	0.8	6.6	3.0	Trace
8	18	1.9	0.8	1.0	5.3	2.7	Trace
9	0	9.4	0.8	2.6	1.5	--	Trace
9	36	9.6	0.5	1.2	5.3	3.5	Trace

Benthic Faunal Analysis

A list by station of the benthic faunal species collected on each station is included in this report (table IV, appendix A). Data at each station are often incomplete and are not quantitative. However, they give an indication of the types of Coelenterata, Mollusca, Polychaeta, Bryozoa, Chordata, Porifera, Annelida, Arthropoda, Brachiopoda, Echinodermata, and organisms of other phyla inhabiting the nearshore environment of the eastern central Chukchi Sea.

DISCUSSION

At the present stage of analysis no definite conclusions can be drawn regarding any aspect of the research carried out. Several sediment samples are yet to be analyzed for the parameters already mentioned here and for some additional ones. Therefore, the discussion that follows must be considered tentative.

The bi- to polymodal size distributions of the barrier beach sediments suggest that these sediments have had a complex depositional history. Presumably, their size distribution is a complex resultant of the effects of periodic storm-induced waves and shorefast ice on deposits laid down normally by the swash and backwash of waves under relatively calm conditions. The possibility that some of the gravels in these barrier beaches may be derived from a relict deposit is not ruled out and if true, this would further complicate the issue. The action of ice on the transport and deposition of sediments in the polar beaches has been speculated on by several investigators but no quantitative data have ever been presented. Present studies on Point Lay sediments and those carried out under another investigation on the North Slope

beaches (Naidu *et al.*, 1970) show that barrier beach sediments from the polar regions have distinctly different size distributions from similar sediments of the low-latitude regions. The difference is in the very poor sorting and the predominance of gravels in polar beach sediments. The gravel-size coal pieces in the Point Lay barrier beach sediments possibly have their source in the coal deposits which outcrop in the adjacent coastal region.

The analyses of the sediment samples completed so far suggest that the chief source of chlorite in the eastern central Chukchi Sea is the adjacent hinterland and that this source probably does not contribute any significant amounts of smectite. Presumably, smectite is transported to the eastern central Chukchi Sea through the Bering Strait, from the Chirikov Basin. Presence of smectite in this basin has been reported by Moll (1970) and the currents necessary to transport it northward are also known to be present (Aagaard and Coachman, 1964). The contrast observed in the relative abundances of clay minerals in sediments from the eastern central Chukchi Sea and Beaufort Sea suggests: (1) a difference in the nature of source material for the sediments of the two seas and/or (2) a difference in physico-chemical processes in the two seas which help to sort out two different assemblages of clay minerals from the same source material. Biscaye (1965) and Griffin *et al.* (1968) have cited latitudinal variations in clay mineral assemblages. The thesis presented by the above authors is supported by results of the study on the Chukchi Sea sediments. However, data from the Beaufort Sea (Naidu *et al.*, 1971) do not run parallel to the trend of clay mineral distributions suggested by Griffin *et al.* (1968).

The analysis of the pore waters of marine sediments has increasingly become an integral and important part of geochemical investigations. These studies have shed some light on the understanding of the origin of brines and early diagenesis. Some interesting patterns of distribution of various ions are evident from figures 8 and 9. Although the concentration of Na^{+} in interstitial water generally increases with depth, at a certain horizon in some cores a minimum is noted. This minimum generally coincides with increased clay content in sediments. It appears that the concentration of Na^{+} in interstitial water is primarily controlled by the amount of clay present in sediments. Similar observations were made in southeastern Alaska (Sharma, 1970a, 1970b and 1970c). These variations in Na^{+} concentrations are related to ion exchanges between Na^{+} in interstitial water and clay particles.

The observed increase of K^{+} with depth in the interstitial waters is believed to be due to dissolution of feldspars as suggested by Garrels and Howard (1959). Similar increase of K^{+} in interstitial waters has been reported by Siever *et al.* (1961, 1965) and Friedman *et al.* (1968).

Decrease in Mg^{++} with depth in interstitial waters has been reported by various authors; however, the explanations offered for such a decrease differ. Some investigators believe that Mg^{++} from interstitial waters is increasingly fixed by clay preferentially over K^{+} with increased depth which is contrary to the conclusion of others who believe in the formation of dolomite. Dolomitization results in simultaneous decrease in magnesium and calcium ions. Recently Drever (1971) proposed that Mg^{++} from interstitial water replaces Fe^{++} in the clay mineral structure. He suggested that removal of Mg^{++} from seawater controls the compositions of interstitial waters in sediments. In view of simultaneous decrease of Mg^{++} and Ca^{++} in the samples we have analyzed we are inclined to conclude that such a decrease is due to the formation of dolomite mineral. This conclusion has to be confirmed by the detection of dolomite which has originated in place, a task that is difficult to accomplish.

The variational trends of Mn^{++} indicate a net upward migration of it by a mechanism similar to that suggested by Bonatti *et al.* (1971). Such upward migration and enrichment generally occurs because of the presence of a reducing environment in the bottom sediment layers. The distinct darker color and release of H_2S from the lower portion of core sediments of the eastern central Chukchi Sea suggest reducing conditions in those sediments at depth. Iron concentrations vary erratically and explanation for this behavior is difficult on the basis of available data. Mn/Fe ratios were considered in an attempt to explain the distribution of iron in the interstitial waters; however, measurements of several other parameters are needed to forward an adequate explanation.

ACKNOWLEDGEMENTS

Ship time for collection of the sediment, benthic fauna and water samples has been provided by the U.S. Coast Guard. We gratefully acknowledge the help and support of Capt. T. L. Roberge, the officers and crew of the U.S.C.G.C. GLACIER. The generous assistance and cooperation extended by Dr. M. C. Ingham of the U.S. Coast Guard, Dr. P. W. Barnes, Jim Trumbull, and John Croizat of the U.S. Geological Survey, and Joe Dygas of the Institute of Marine Science during sample collection are greatly appreciated. Dr. D. C. Burrell and Mr. Meng-Lein Lee are responsible for the trace-metal analysis of sea water. Mr. George J. Mueller identified the benthic fauna, and Dr. Peter McRoy and Sam Stoker were concerned with this aspect of work. We are indebted to Dr. D. M. Hopkins, Marine Geology Section, U.S. Geological Survey for his technical advice.

The geological work has been supported by the U.S. Geological Survey, Marine Geology Branch, Contract 14-09-001-12559.

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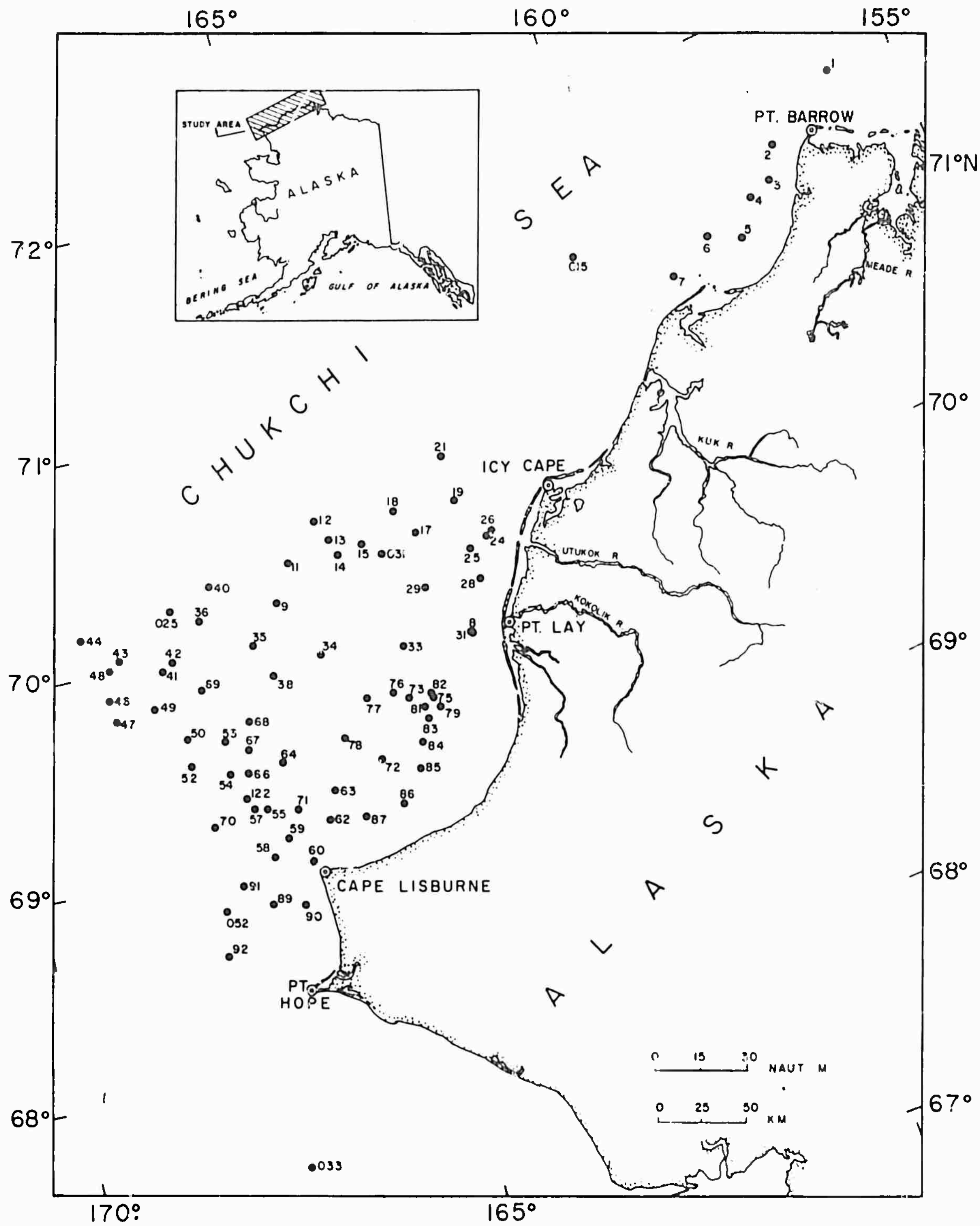

Figure 1.—Location of bottom sediment samples collected in the eastern central Chukchi Sea, 22 September–18 October 1970, during WEBSEC–70. The four stations prefixed by 0 were obtained from previous University of Washington cruises.

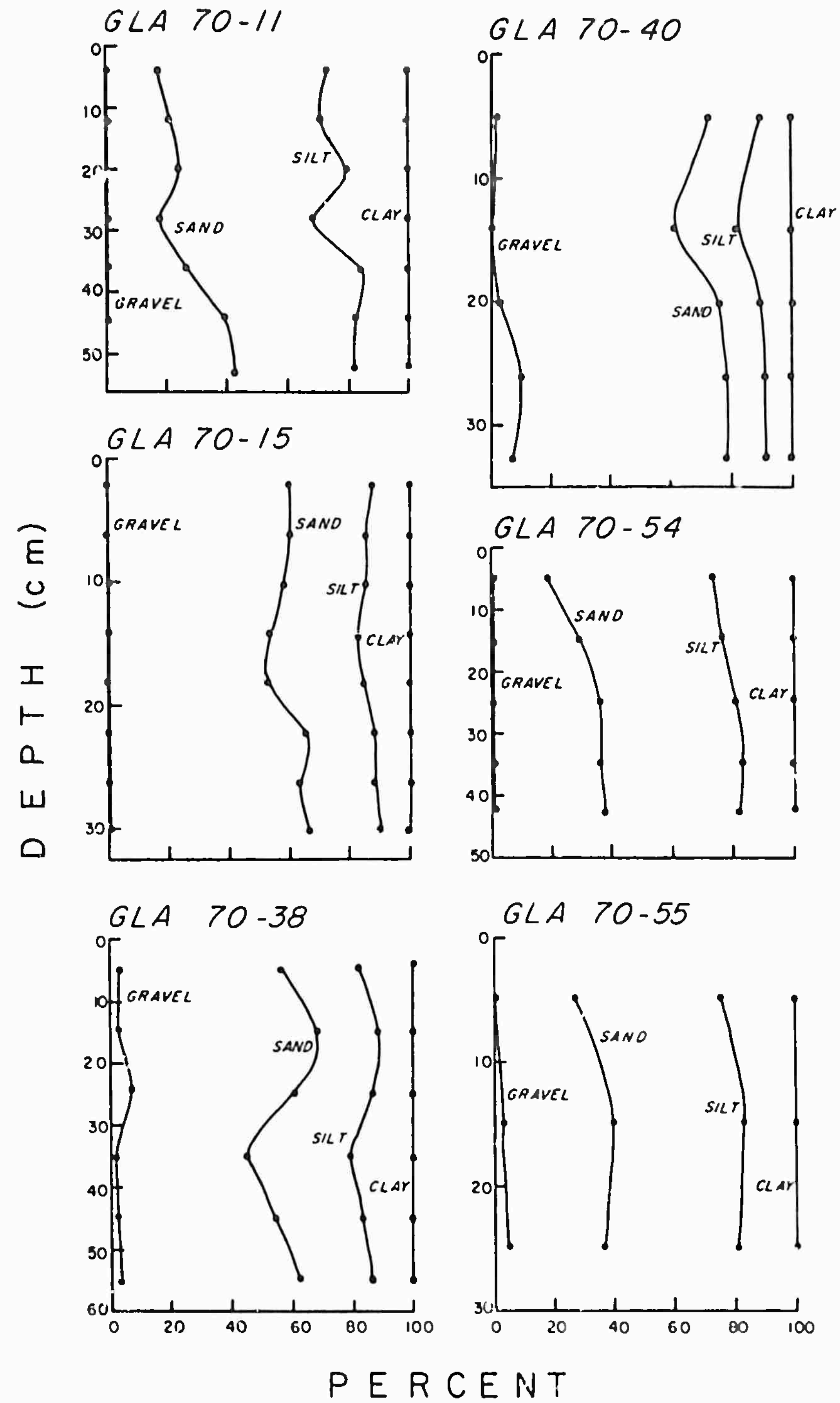

Figure 2.—Distributions of gravel-sand-silt-clay percentage composition in eastern central Chukchi Sea core samples collected during WEBSEC–70.

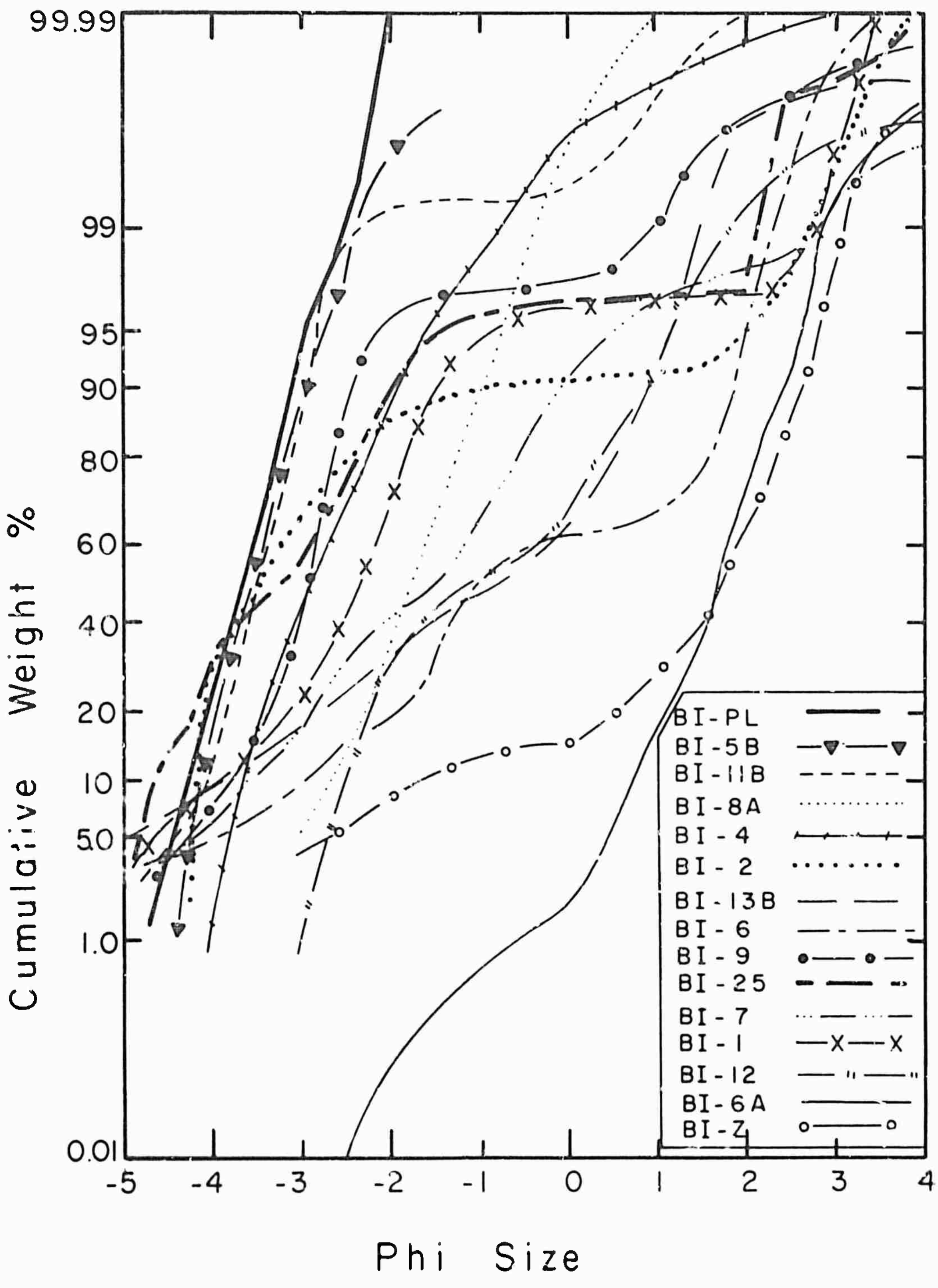

Figure 3.—Size distribution of barrier beach sediments collected at Point Lay on 25 September 1970 during WEBSEC-70.

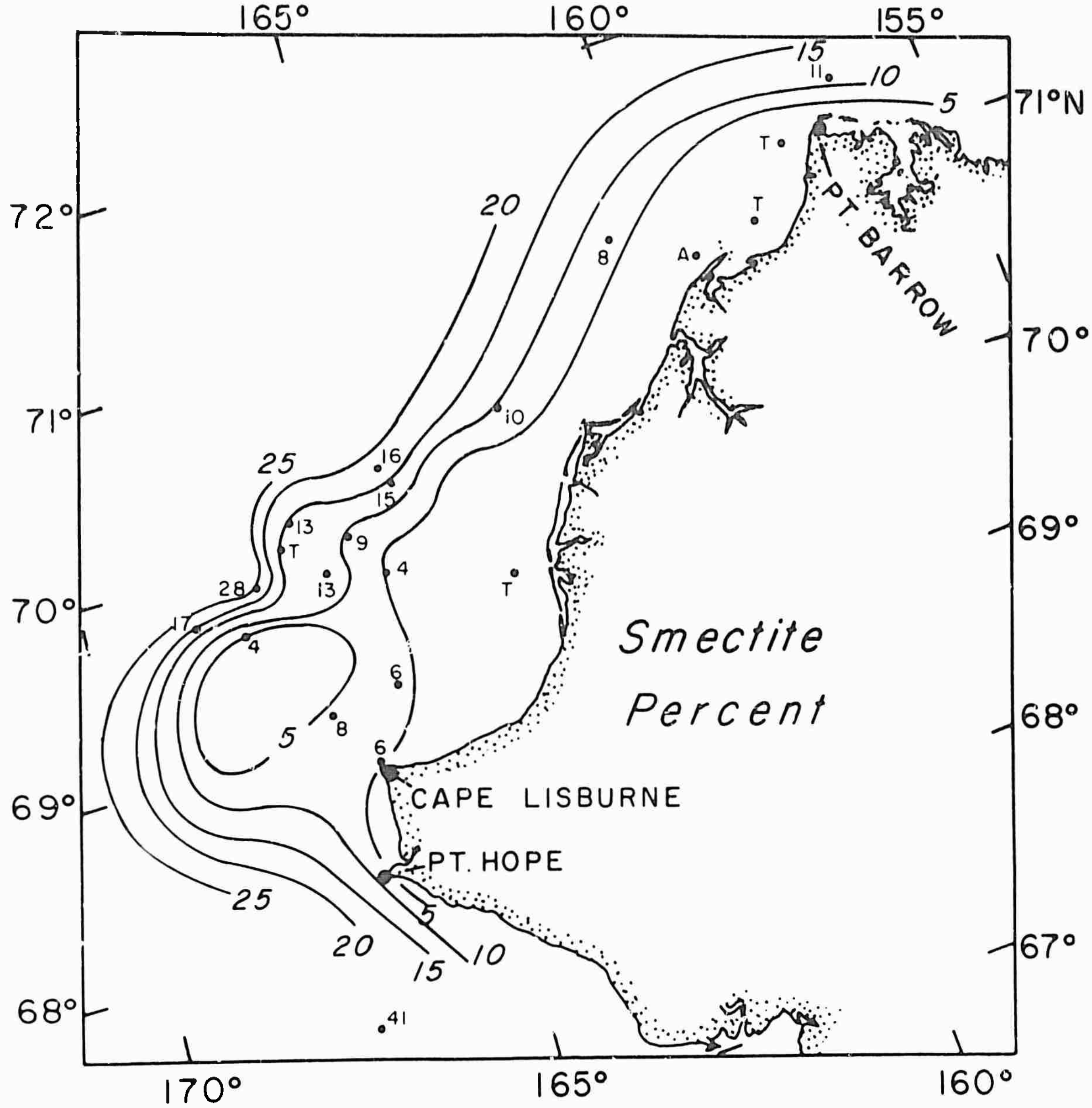

Figure 4.—Distribution of smectite concentration (%) in bottom sediments of the eastern central Chukchi Sea collected during WEBSEC–70.

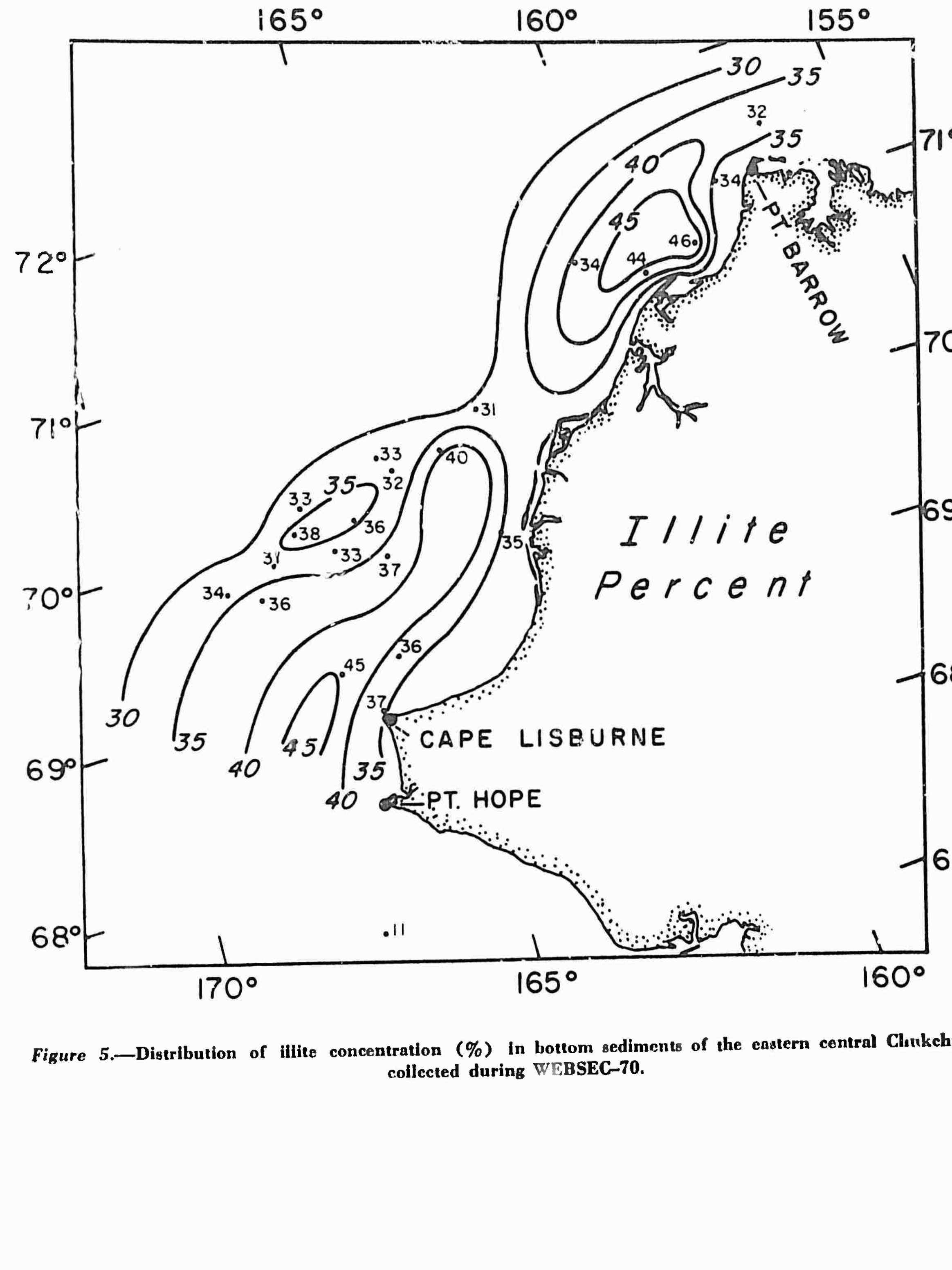

Figure 5.—**Distribution of illite concentration (%) in bottom sediments of the eastern central Chukchi Sea collected during WEBSEC–70.**

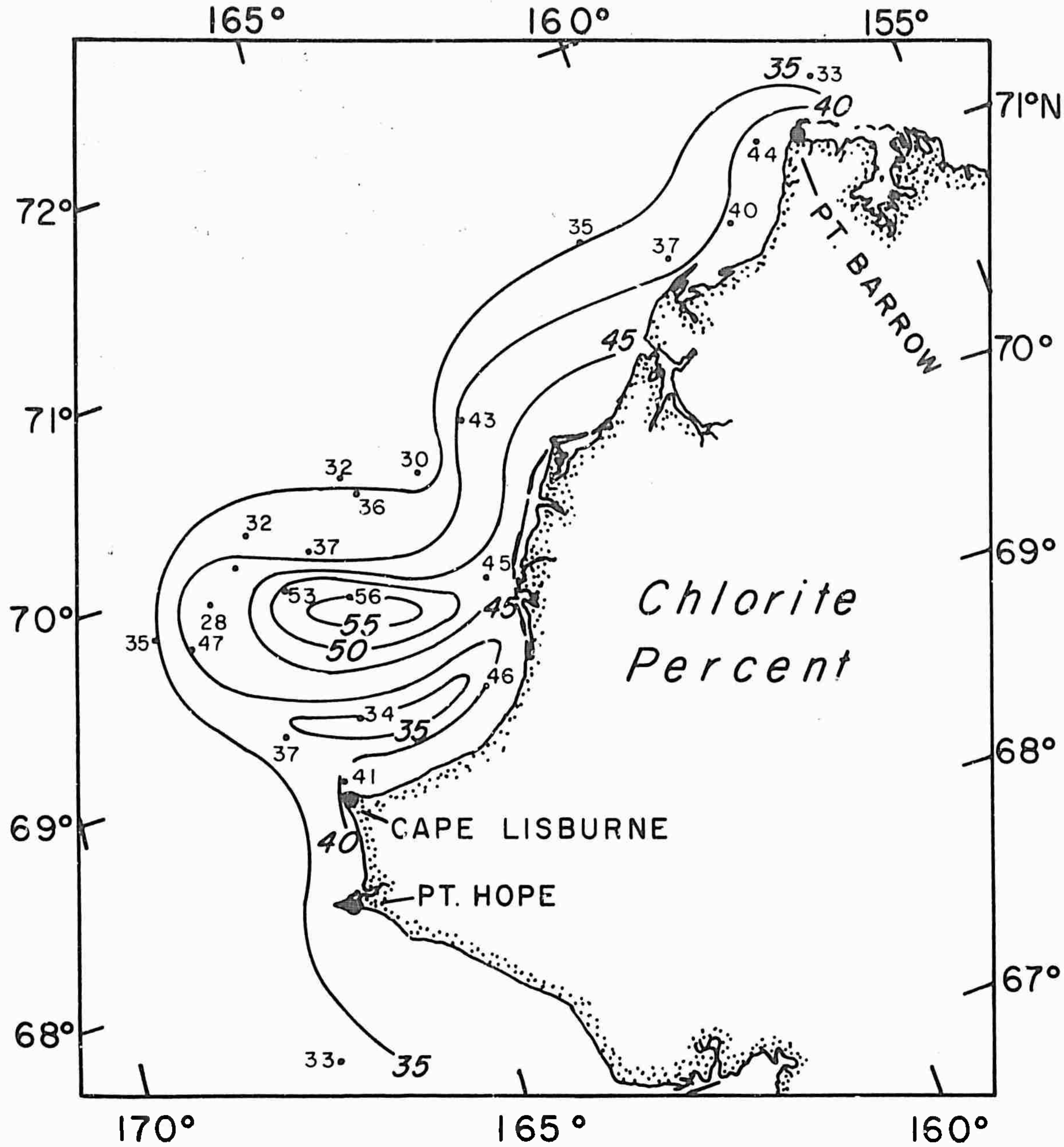

Figure 6.—**Distribution of chlorite concentration (%) in bottom sediments of the eastern central Chukchi Sea during WEBSEC–70.**

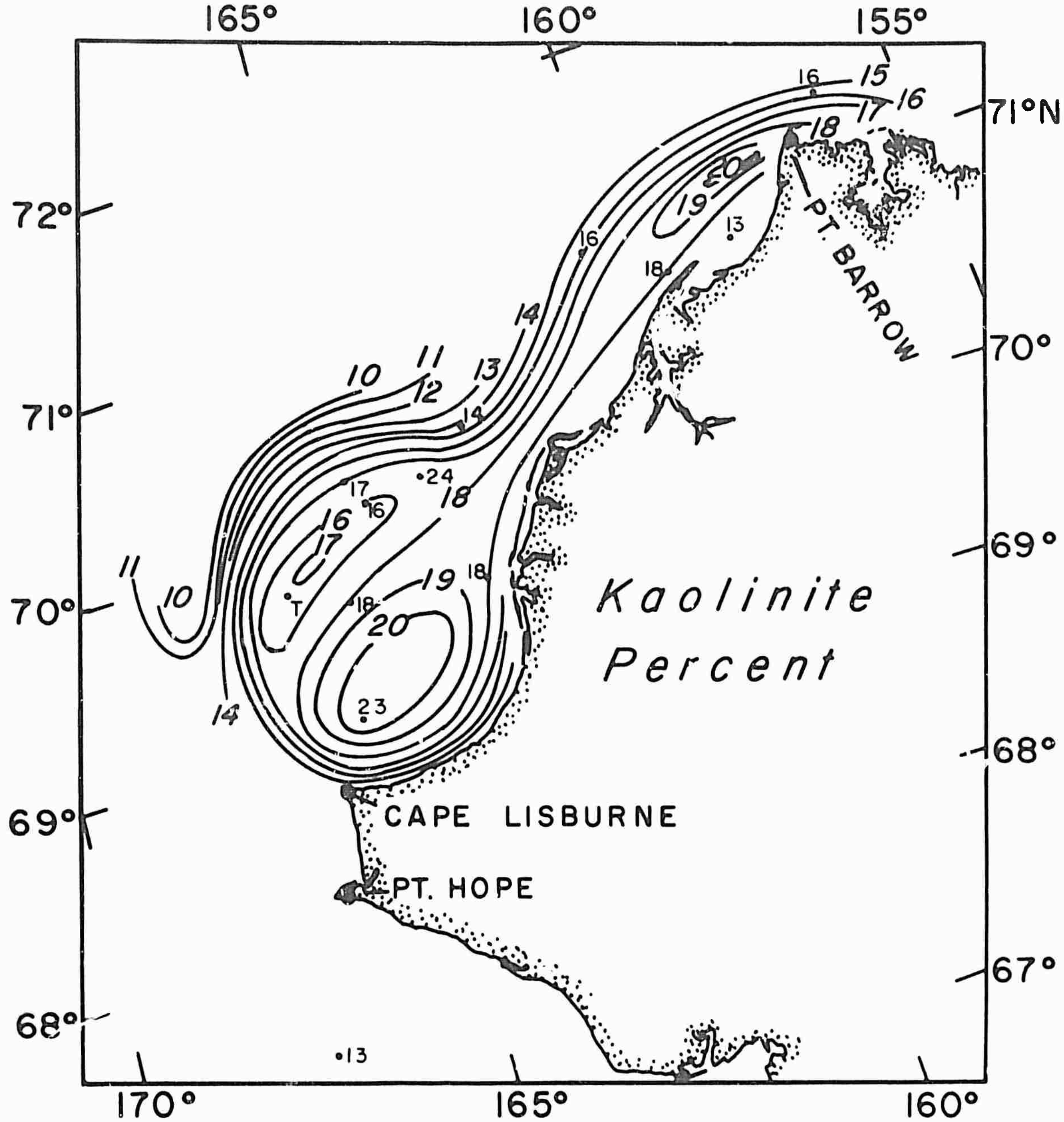

Figure 7.—**Distribution of kaolinite concentration (%) in bottom sediments of the eastern central Chukchi Sea collected during WEBSEC–70.**

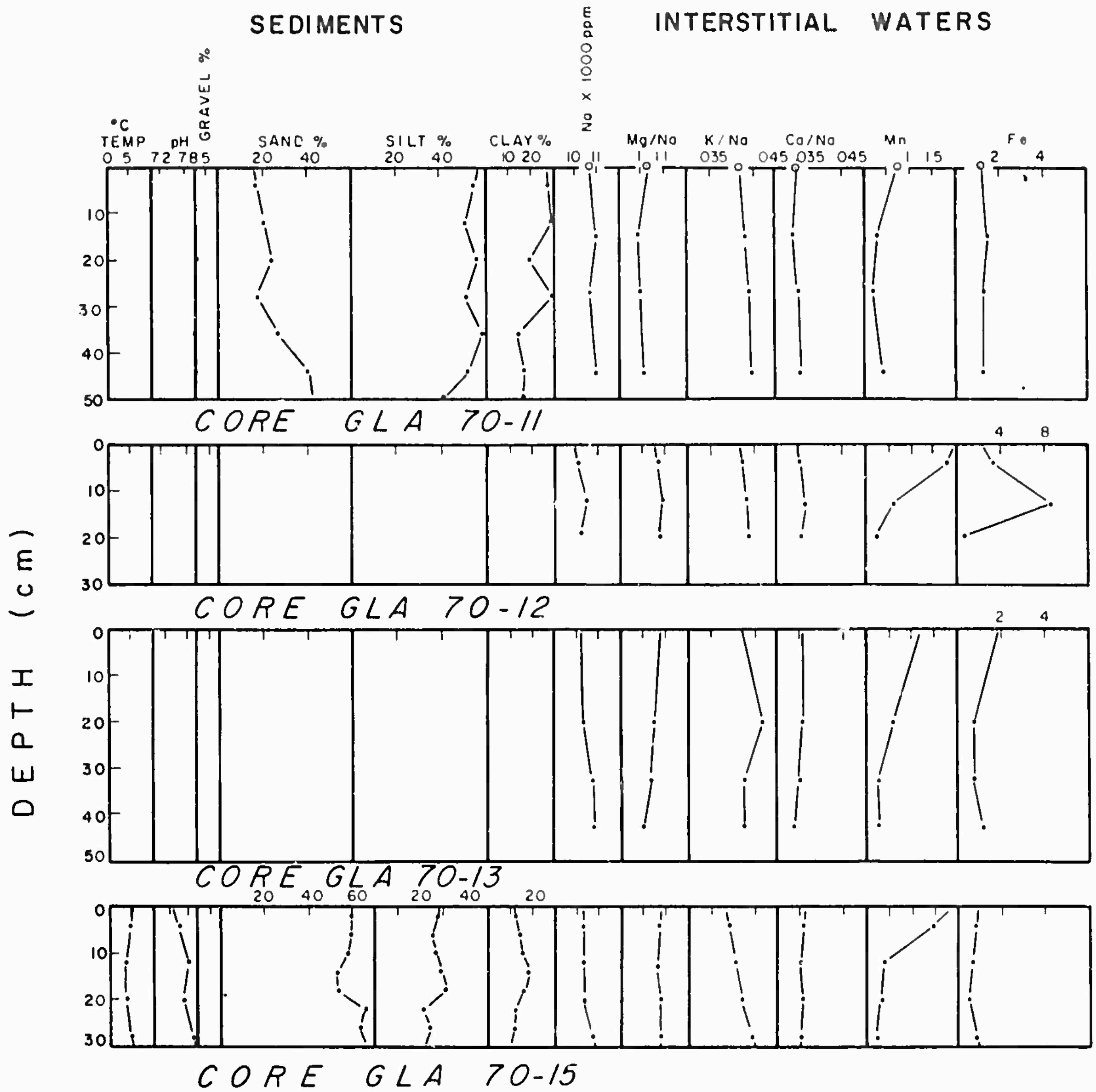

Figure 8.—**Relationship between the concentrations of metal ions in interstitial waters and the pH, temperature, and texture of bottom sediments of the eastern central Chukchi Sea collected during WEBSEC–70, stations 11, 12, 13 and 15.**

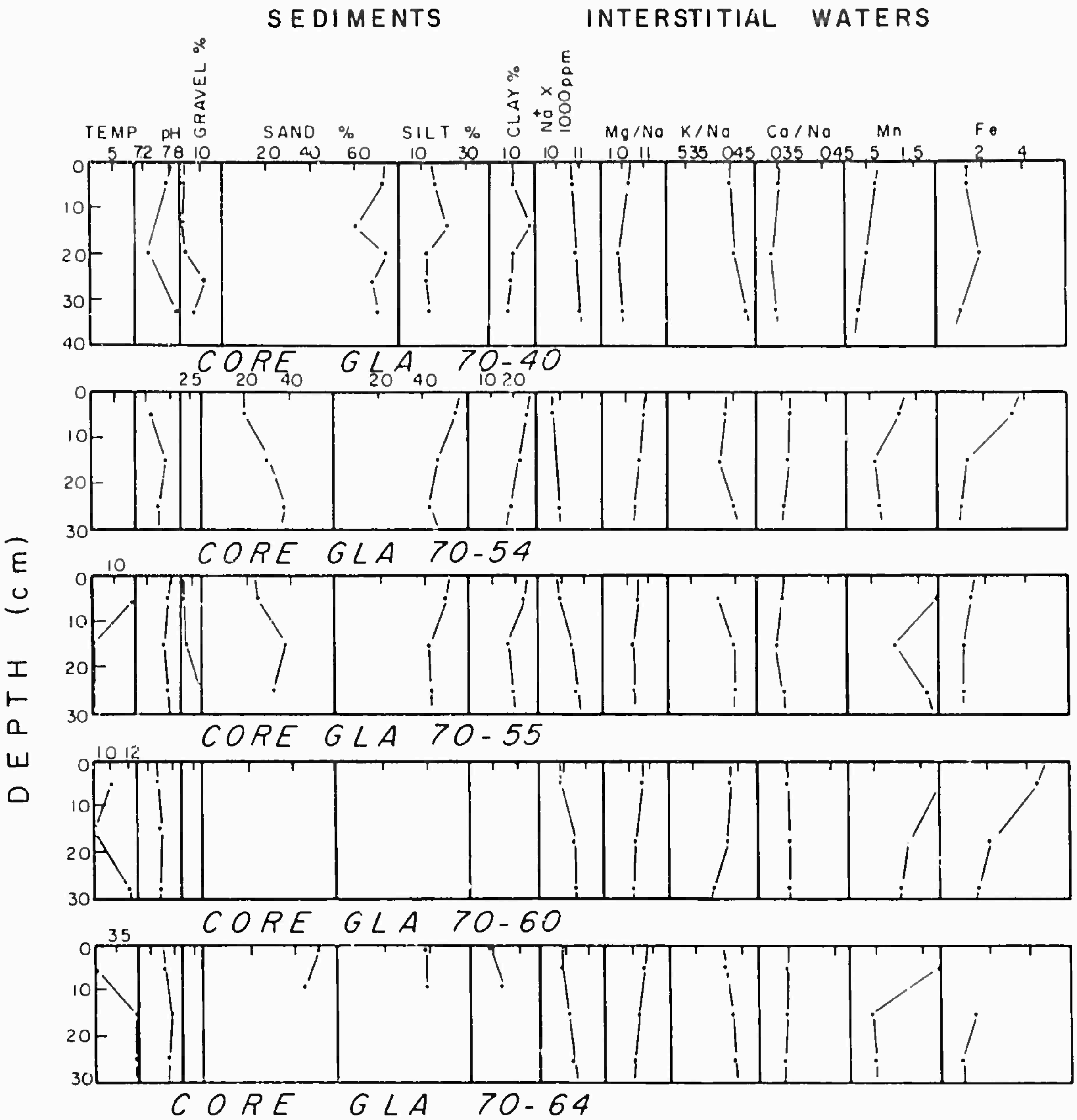

Figure 9.—Relationship between the concentrations of metal ions in interstitial waters and the pH, temperature, and texture of bottom sediments of the eastern central Chukchi Sea collected during WEBSEC–70, stations 40, 54, 55, 60 and 64.

Appendix A—Data

Table I.—Ionic concentrations in interstitial waters, texture, temperature and pH of core sediments collected during WEBSEC–70.

Station Number	Depth (cm)	Sediment Gravel %	Sediment Sand %	Sediment Silt %	Sediment Clay %	Temp. °C	pH	Interstitial Water (conc. in ppm) Na+	Mg++	K+	Ca++	Mn++	Fe++	P+ +
GLA 70–9	0–10						7.24	10,660	1,100	500	390	0.60	0.87	0.03
GLA 70–11	Grab							10,330	1,086	460	380	1.85	6.12	0.32
GLA 70–11	0–4	0.00	17.96	54.58	27.46			10,660	1,100	450	375	0.75	1.12	0.03
	13–17	0.00	20.84	50.43	28.72			11,000	1,086	473	375	0.30	1.50	
	24–30	0.00	18.05	50.45	31.50			10,660	1,060	470	375	0.20	1.25	
	42–47	0.19	40.25	42.11	17.45			11,000	1,115	490	390	0.40	1.25	
GLA 70–12	Grab							10,660	1,100	445	380	1.50	2.50	0.14
	0.75							10,160	1,092	430	360	1.80	3.40	0.10
	7.5–15							10,500	1,145	455	385	0.60	8.63	
	15–23							10,330	1,115	455	370	0.25	0.69	
GLA 70–13	0–5							10,330	1,115	435	370	1.20	1.87	0.05
	15–25							10,330	1,086	482	370	0.60	0.25	
	30–35							10,660	1,105	455	375	0.30	0.75	
	40–45							10,830	1,086	463	370	0.30	1.19	
GLA 70–15	0–8	0.05	59.84	25.89	14.22	5.0	7.63	10,330	1,115	405	375	1.50	0.87	
	8–16	0.02	53.52	28.74	17.72	4.0	7.85	10,330	1,100	420	365	0.40	0.75	
	16–24	0.00	65.72	21.99	12.28	4.0	7.70	10,330	1,115	435	370	0.35	0.50	
	24–32	0.16	67.59	22.46	9.79	5.0	7.92	10,660	1,150	473	380	0.25	0.87	
GLA 70–35	0–5									468	365	0.55	1.87	0.04
GLA 70–36	0–4							10,660	1,105	450	370	0.80	2.50	0.06
	11–15							11,000	1,120	500	375	0.70	1.63	
GLA 70–38	0–10	3.58	52.85	26.14	17.43	19.5	7.33	10,330	1,050	480	355	0.70	3.75	0.07
	18–25	7.71	53.55	25.46	13.28			10,500	1,060	475	355	1.00	4.94	
GLA 70–40	0–10	0.86	72.56	16.51	10.07		7.73	10,660	1,093	475	375	0.70	1.50	
	18–22	3.01	74.23	12.62	10.14		7.31	10,830	1,060	492	365	0.50	2.00	
	30–35	7.67	70.50	13.42	8.41		7.94	11,000	1,093	525	380	0.30	1.13	
CLA 70–42	0–10					15.0	7.39	10,330	1,020	475	360	0.95	4.25	0.09
	10–20					18.0	7.33	10,660	1,000	450	355	0.90	16.25	
GLA 70–44	0–10							11,000	1,075	510	370	0.30	1.75	0.05
GLA 70–49	0–6							10,330	1,090	485	360	0.42	0.63	0.02
	6–12							10,500	1,100	485	370	0.45	1.06	
GLA 70–54	0–10	0.09	19.63	54.41	25.86	11.9	7.36	9,660	1,050	415	360	1.20	4.37	
	10–20	0.05	30.29	47.19	22.47	12.0	7.64	10,660	1,100	430	340	0.65	1.37	
	20–30	0.42	37.29	43.20	19.09	13.5	7.51	10,000	1,050	450	360	0.75	1.13	
GLA 70–55	0–10	1.14	25.99	49.14	23.73	11.0	7.70	10,000	1,060	410	355	2.00	1.50	0.02
	10–20	3.06	37.69	42.22	17.02	9.0	7.62	10,500	1,090	470	360	1.05	1.25	
	20–30	5.30	32.47	43.02	19.21	9.0	7.71	10,660	1,110	480	380	1.75	1.25	
GLA 70–60	0–10					10.0	7.46	10,000	1,070	435	360	2.20	4.37	0.07
	15–20					8.0	7.53	10,660	1,090	460	380	1.30	2.25	
	25–30					12.0	7.53	10,660	1,100	430	380	1.15	1.75	
GLA 70–64	0–10					3.0	7.60	10,000	1,080	420	360	2.00	0.02	
	10–20					4.0	7.55	10,330	1,090	450	370	0.50	1.56	
	20–30					4.0	7.77	10,500	1,090	465	370	0.55	1.00	

Table II.—Grain-size parameters of barrier beach sediments at Pt. Lay, Alaska on 25 September 1970, during WEBSEC–70.

St. No.	Mdø	M_zø	σ_Iø	Sk_I	K_G
BI–1	–2•50	–2•53	0•98	–0•18	1•50
BI–2	–3•50	–3•26	1•00	0•52	1•98
BI–4	–2•90	–2•86	0•67	0•08	0•93
BI–5B	–3•55	–3•56	0•44	0•03	0•91
BI–6A	1•70	1•60	0•64	–0•13	0•99
BI–6	–1•05	–0•95	2•20	0•02	0•86
BI–7	–1•50	–1•66	1•33	–0•17	1•01
BI–8A	–1•75	–1•76	0•64	–0•08	1•06
BI–9	–2•90	–2•98	0•57	–0•32	1•57
BI–11B	–3•45	–3•46	0•44	–0•10	1•15
BI–12	–1•15	–0•96	1•33	0•21	0•73
BI–13B	–0•90	–1•13	1•89	–1•00	0•87
BI–PL	–3•55	–3•63	0•45	–0•23	1•02
BI–25	–3•25	–3•30	1•03	0•01	0•85
BI–Z	1•75	1•45	1•40	–0•66	1•61

Table III.—Types and abundances (in percent) of clay minerals in the eastern central Chukchi Sea bottom sediments collected during WEBSEC–70 (GLA), or collected by the University of Washington (SI, BB).

Station No.	Water Depth (m)	Illite		Smectite		Chlorite		Kaolinite		Kaolinite Chlorite Ratios	Chlorite Illite Ratios
		A	B	A	B	A	B	A	B	A or B	B
GLA–70–1	143	39•7	59•4	12•5	4•7	28•7	21•5	19•1	14•3	0•67	0•36
GLA–70–2	19	34•3	51•2	Tr	Tr	44•8	33•3	20•8	15•5	0•47	0•65
GLA–70–5	44	46•3	63•3	Tr	Tr	40•4	27•5	13•4	9•2	0•33	0•43
GLA–70–7	40	44•4	61•5	Ab	Ab	37•0	25•7	18•5	12•8	0•50	0•42
SI–015	35	39•1	58•1	8•7	3•2	36•0	26•7	16•2	12•0	0•45	0•46
GLA–70–8	30	35•2	52•2	Tr	Tr	46•2	34•1	18•5	13•7	0•40	0•65
GLA–70–9	38	36•4	55•2	9•1	3•5	37•5	28•4	17•0	12•9	0•45	0•51
GLA–70–12	19	33•3	53•3	16•7	6•7	32•6	26•1	17•4	13•9	0•53	0•50
GLA–70–13	20	32•2	51•7	15•2	6•1	36•3	29•1	16•3	13•1	0•45	0•56
GLA–70–18	45	40•0	58•1	4•6	1•7	30•8	22•2	24•6	17•9	0•81	0•38
GLA–70–21	51	31•6	50•0	10•5	4•2	43•4	34•3	14•5	11•5	0•34	0•69
GLA–70–34	35	37•8	57•1	4•4	1•6	56•1	31•0	18•7	10•3	0•33	0•54
GLA–70–35	38	33•3	52•6	13•3	5•3	53•3	42•1	Tr	Tr	——	0•80
GLA–70–36	45	38•5	55•6	Tr	Tr	44•0	31•7	17•6	12•7	0•40	0•57
GLA–70–40	32	33•3	52•6	13•3	5•3	38•1	30•1	15•2	12•0	0•40	0•57
GLA–70–42	24	31•4	53•7	28•6	12•2	28•9	24•6	11•1	9•5	0•39	0•48
GLA–70–46	44	34•8	55•2	17•4	6•9	35•9	28•4	12•0	9•5	0•33	0•51
GLA–70–49	47	36•5	54•5	4•8	1•8	47•7	35•5	11•7	8•3	0•23	0•65
GLA–70–57	28	45•2	56•6	8•1	3•0	37•4	28•0	16•6	12•4	0•44	0•49
GLA–70–60	35	37•1	55•4	6•4	2•4	41•1	30•7	15•4	11•5	0•37	0•55
GLA–70–63	35	36•4	54•5	6•1	2•3	34•5	25•9	23•0	17•2	0•66	0•48
BB–038*	46	11•3	25•5	41•5	23•4	33•7	37•1	13•5	14•9	0•40	1•45
GLA–70–93**	35	33•3	53•3	16•7	6•7	Unresolved		Unresolved		——	——
GLA–70–94**	35	35•8	57•1	20•9	8•3	28•9	23•0	14•4	11•5	0•50	0•40

A: Non-weighed peak-area percentages considered
B: Weighted peak-area percentages (after Biscaye, 1965, p. 808) considered.
*Sample from S.E. Chukchi Sea; 60 miles due S. of Pt. Hope
**Samples from Chirikov Basin due S. of Bering Strait
Tr. Traces
Ab: Absent

Table IV.—Benthic organisms collected in the eastern central Chukchi Sea during WEBSEC-70.

Station 1
GLA— 9-22-70
71°35' N 155°50' W
D/T GMT 231900
Depth: 143 m

COELENTERATA
Eunephthya rubiformis

POLYCHAETA
Chrone infundibuliformis

MOLLUSCA
Trophanopsis pacificus

BRYOZOA
Eucratea loricata
Myriozoam subgracile

CHORDATA
Boltenia ovifera

Station 3
GLA— 9-23-70
70°14' N 157°22' W
D/T GMT 240528
Depth: 53.1 m

PORIFERA
Echinoclathria beringensis

COELENTERATA
Eudendrium annulatum
one or more sp.—unknown hydroids
Stylasleria sp.
Eunephthya rubiformis

ANNELIDA
Syllis fasciata
Nephtys ciliata
Terebellides stroemi

ARTHROPODA
Caprella striata
Hyas coarctatus
several species of unknown amphipods including 2 Gammaridians

MOLLUSCA
Astarte fabula
Clinocardium sp.
Macoma calcarea
Mysella compressa
Thyasira gouldii
Trophanopsis pacificus
Margarites costalis

BRACHIOPODA
Hemithiris psittacea

BRYOZOA
Bidenkapia spitsbergensis
Eucratea loricata
Myriozoum subgracile
Rhamphostomella fortissima

ECHINODERMATA
Gorgonocephalus caryi
Psolidium bullatum

CHORDATA
Boltenia ovifera

Station 4
GLA— 9-24-70
71°10' N 157°42' W
D/T GMT 241714
Depth: 40 m

ANNELIDA
Chone duneri
Pectinaria auricoma

ARTHROPODA
Byblis sp. (Amphipoda)
unknown sp. (Amphipoda)

MOLLUSCA
Tachyrhynachus arosus

Station 5
GLA— 9-24-70
+0.991 m seive
71°02' N 158°02' W
D/T GMT 241846
Depth: 22 m

ANNELIDA
Lumbrinereis fragilis
Rhodine sp.

ARTHROPODA
unknown sp. (Amphipoda)

Station 6
GLA— 9-24-70
+2.8 mm seive
71°06' N 158°31' W
D/T GMT 242035
Depth: 24 m

COELENTERATA
unknown sp. (anemone)

ANNELIDA
Nepthys sp.

MOLLUSCA
Venericardito sp.
Crenella dicussata
Venericardia crebricostata

Hiatella arctica
Admete conthonyi
Margarites sp.
Natica clausa
unknown sp. (gastropods)

BRACHIPODA

Terebratulina sp.

Station 7
GLA— 9-24-70
+0.99 mm
71°00' N 159°12' W
D/T GMT 242255
Depth: 40 m

COELENTERATA

Sertularia sp.
unknown sp. (anemone)

ANNELIDA

Etone longa
Phyllodoce mucosa
Nephtys ciliata
Harmothoe extenuata
Phyllodoce citrina
Glycera tridactyla
Chaetozone setosa
unknown sp. (polycheate)

BRYOZOA

Umbonula patens

MOLLUSCA

Hiatella arctica
Trophanopsis pacificus
Ischnochiton albus?

ARTHROPODA

Balanus glandula
Amphipod unknown sp.

SIPUNCULIDA

Goldfingia margaritacea

Station 8
GLA— 9-26-70
69°45' N 163°34' W
D/T GMT 251944
Depth: 30 m

ANNELIDA

Pectinaria granulata

ECHINODERMATA

Stegophiura nodosa

ARTHROPODA

Pagurus aleuticus

MOLLUSCA

Mya pseudoarenaria

CHORDATA

Corella borealis

Station 9
GLA— 9-27-70
70°10' N 166°03' W
D/T GMT 280005
Depth: 38 m

ANNELIDA

Antinoella badia
Maldanidae 1 species

ARTHROPODA

Cumaceans
several unknown Amphipods

MOLLUSCA

Yoldiella oleacina

ECHINODERMATA

Echiurus echiurus

Station 12
GLA— 9-28-70
70°28' N 165°15' W
D/T GMT 290005
Depth: 19 m

ARTHROPODA

Cumacea—one unknown species
Amphipoda—one unknown species

MOLLUSCA

Nuculana radiata

ECHINODERMATA

Amphiodia craterodmeta
Echiuris echiuris

Station 15
GLA— 9-29-70
unsieved sample
70°18' N 164°41' W
D/T GMT 292340
Depth: 43 m

ANNELIDA

Axiothella catenata
Terebellides stroemi
Pectinariidae sp.

NEMERTINEA

Cerebratulus sp.

ARTHROPODA

unknown Amphipod

MOLLUSCA

Macoma calcarea
Nucula tenuis
Sulcoretusa sp.

ECHINODERMATA

Echiuris echiuris
Amphiodia craterodmeta

Station 18
GLA— 9-30-70
70°24′ N 164°02′ W
D/T GMT 301736
Depth: 38 m

ANNELIDA

Nephtys sp.
Lumbrinereis similaris
Glycinda armigera
Magelona japonica
Glycera sp.
Myriochele heeri
Praxillella gracilis
Maldane sarsi
Maldane glebifex
Maldanida—one or two unknown sp.

NEMERTINEA

Cerebratulus sp.

ARTHROPODA

Cumacea—unknown sp.
Amphipoda—3 unknown sp.

MOLLUSCA

Polinices caurinus
Beringius sp.
Oenopota sp.
Yoldia hyperborea

Station 19
GLA— 9-30-70
+2.8 mm sieve
70°10′ N 166°03′ W
D/T GMT 010005
Depth: 31 m

ANNELIDA

Lumbrineris fragilis
Glycera sp.
Nepthys sp.

MOLLUSCA

Astarte borealis
Liocyma fluctuosa

ECHINODERMATA

Stegophiura nodosa
Echinarachnius parma

ARTHROPODA

Balanus crenatus

CHORDATA

Mogula sp.

Station 21
GLA— 10-1-70
+2.8 mm sieve
70°34′ N 163°16′ W
D/T GMT 012346
Depth: 38 m

NEMATODA

unknown species

ANNELIDA

Cirratulus cirratus
Glycera tridactyla
Magelona japonica
Chone infoundibuliformis
Axiothella catenata

MOLLUSCA

Yoldia hyperborea
Sorripes groenlandicus
Yoldia scissurata
Macoma calcarea
Astarte alaskensis
Venericardia cribricostata
Liocyma fluctuosa
Nucula tennis
Myselia sp.
Polynicies sp.

ECHINODERMATA

Ophiura quadrispina

ARTHOPODA

Taneidacea—unknown species
Cumacea—unknown species
Amphipoda—unknown species

Station 23
GLA— 10-2-70
+2.8 mm sieve
70°23′ N 162°24′ W
D/T GMT 022030
Depth: 24 m

PROTOZOA

large foram

NEMERTINEA

Cerebratulus sp.

ANNELIDA

Glycinde armigera
Travisia forbesii
Glycera tridactyla

MOLLUSCA

Venericardita cribricostata
Serripes groenlandicus
Spisula alaskana
Liocyma fluctuosa
Sulcoretusa sp.
Margarites pribeloffensis
Turritellopsis sp.

ARTHROPODA

unknown sp.—Amphipoda

ECHINODERMATA

Ophiura sp.

Station 24
GLA— 10-3-70
+0.99 mm sieve
70°09' N 162°57' W
D/T GMT 030200
Depth: 20 m

PROTOZOA

large foram

ANNELIDA

Etone longa
Glycera tridactyla
Travisia forbesii
Glycinde armigera

MOLLUSCA

Macoma calcarea
Yoldia limatulata
Liocyma fluctuosa
Spisula alaskana
Margarites sp.
Cylichna sp.

ECHIURIDA

Echuris echuris alaskansis

ARTHROPODA

unknown sp.—Amphipoda

Station 28
GLA— 10-4-70
+2.8 mm sieve
69°59' N 163°17' W
D/T GMT 041700
Depth: 30 m

ANNELIDA

Glycera tridactyla

MOLLUSCA

Macoma calcarea
Hiatella arctica
Astarte borealis
Nucula tenius
Serripes groenlandicus
Yoldia limatulata
Mya psuedoarenaria
Mysella beringensis
Turritellopsis sp.
Polinices caurinus
unknown sp.—gastropoda
Retusa semen

Preliminary Report on the Zooplankton Collected on WEBSEC–70

Bruce L. Wing[1]

During WEBSEC–70 zooplankton were collected by three methods. Seventy-seven quantitative samples were taken by vertical tows with a 0.5–m diameter, 0.57-mm mesh, Norpac standard net, and four qualitative surface samples were taken with a 12-cm diameter, 0.16-mm mesh, Wisconsin phytoplankton net (fig. 1 and table 1). Additional qualitative zooplankton samples were obtained as incidental catch in an Isaacs-Kidd midwater trawl used for capturing small fishes (Quast, elsewhere in this Oceanographic Report).

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The qualitative samples of macroplankton from the Isaacs-Kidd midwater trawl catches are being held as source material for future taxonomic investigations on amphipods and mysids.

Sixty-two categories of marine zooplankton, including species and distinctive life history stages, have been identified from the quantitative samples (figs. 2 and 3, and table 2). A manuscript on the relationship of zooplankton distributions to oceanographic conditions is in preparation.

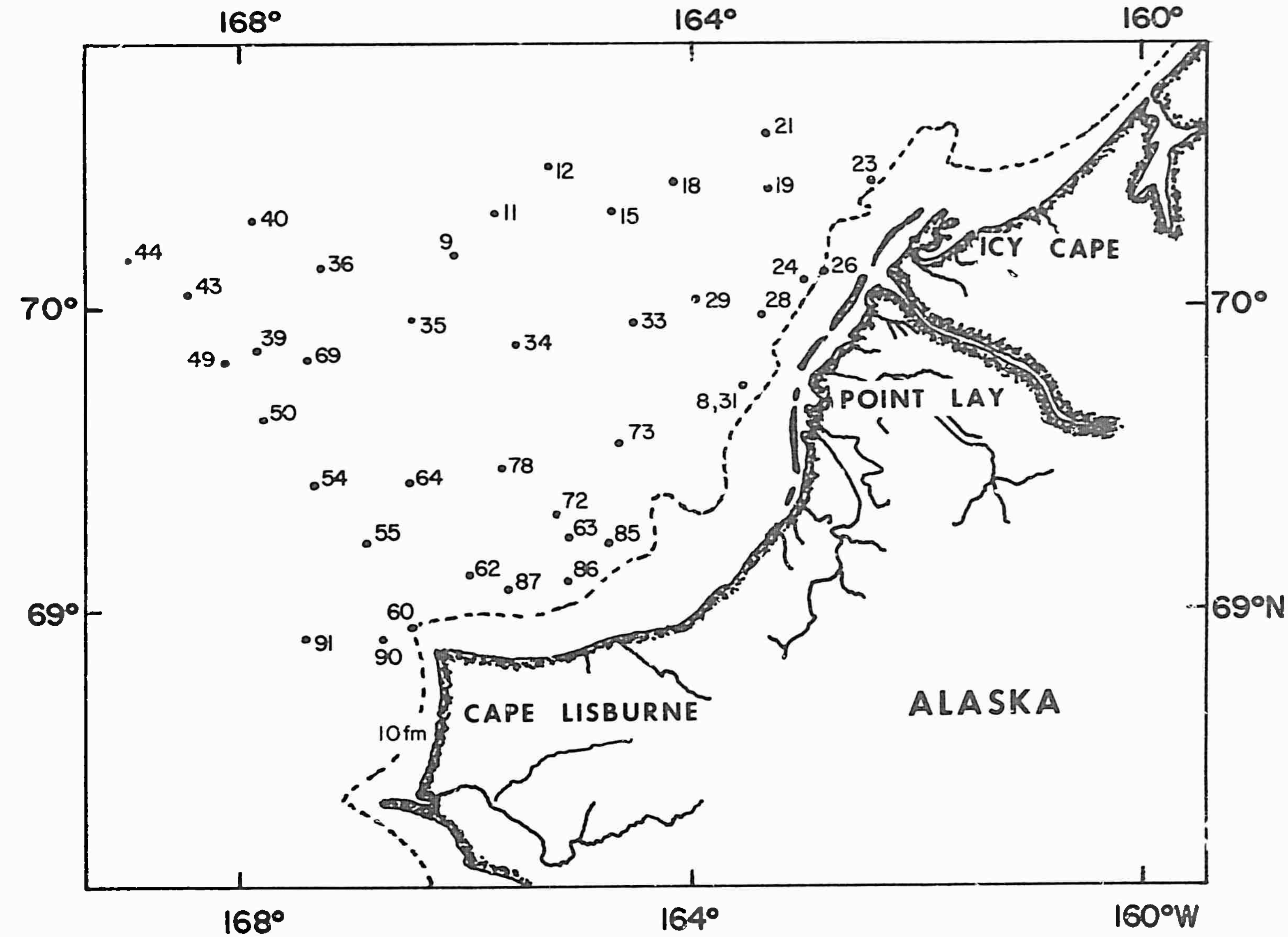

Figure 1.—Location of stations on which vertical tows were made for zooplankton samples during WEBSEC–70.

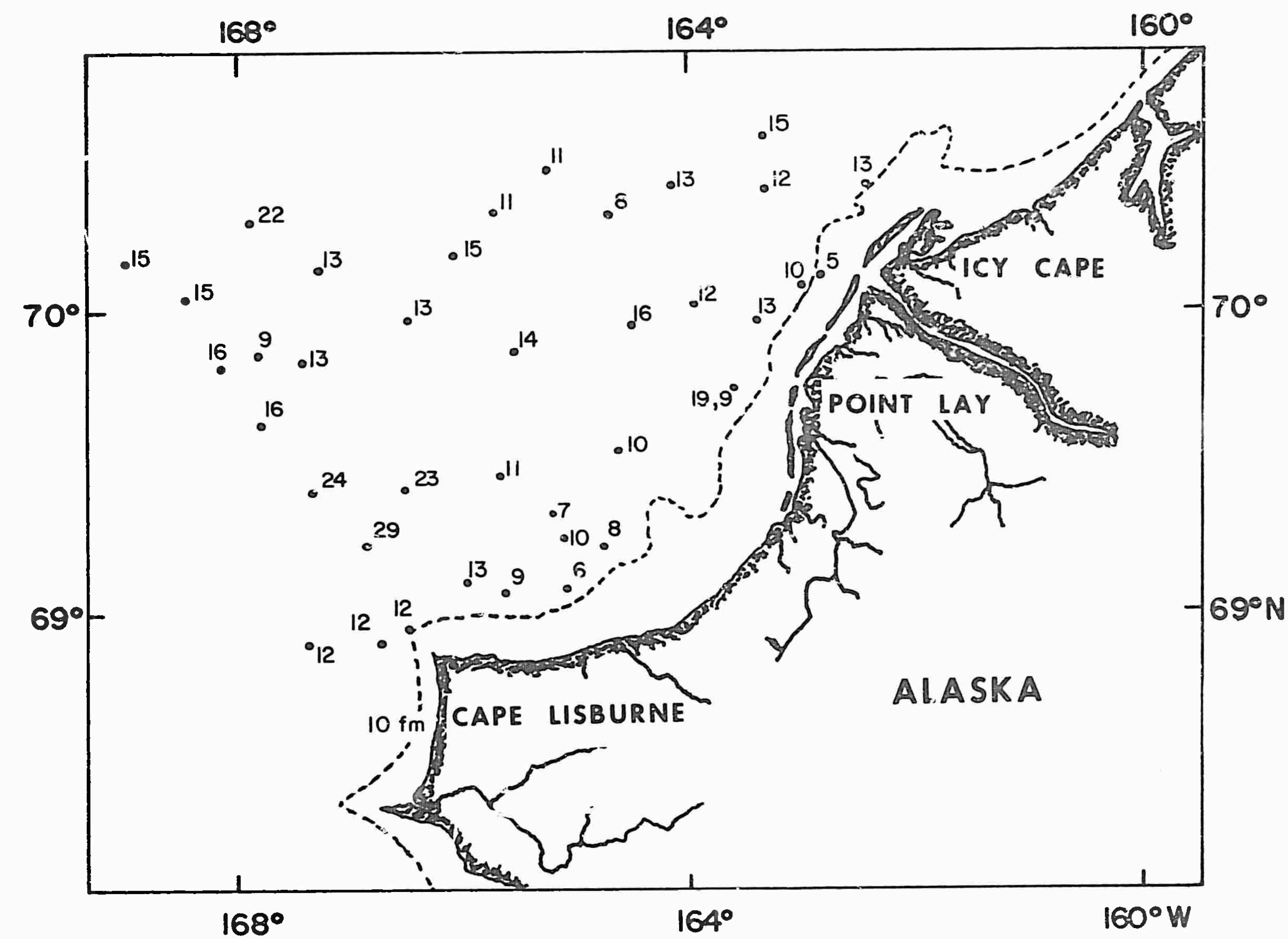

Figure 2.—Number of zooplankton species collected at each station by vertical net tows during WEBSEC–70.

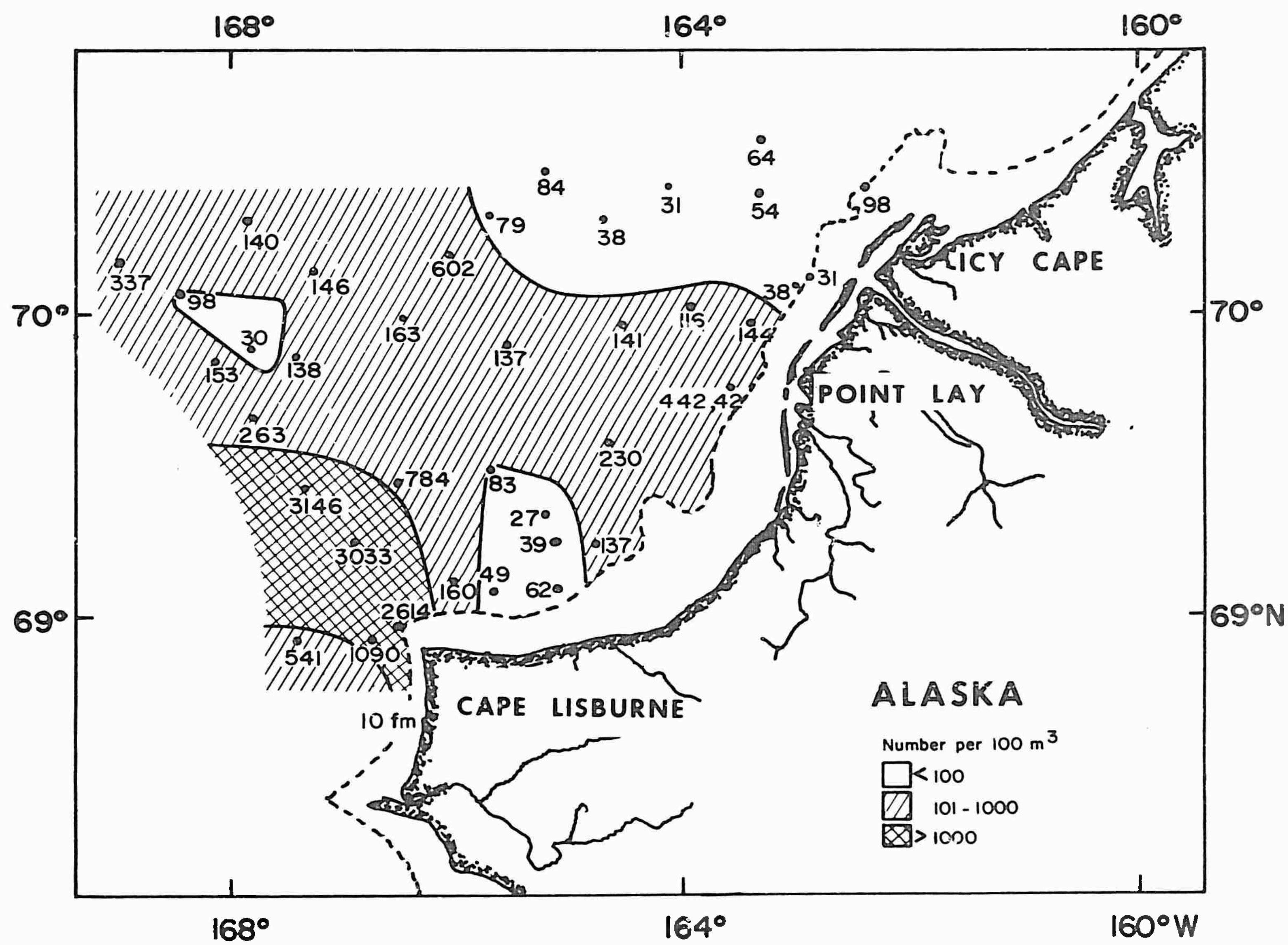

Figure 3.—Concentration (individuals/100 m³ of water) of calanoid copepods sampled by vertical net tows during WEBSEC–70.

Table 1.—Station data for zooplankton samples taken during WEBSEC–70.

Station	Position Lat. N	Long. W	Sampling depth (m)	Date	Times BST	Comments
8	69°45′	163°34′	17	9/26	22:25 22:30	Times to nearest 5 min.
9	70°10′	166°03′	42	9/27	15:45 15:50	
11	70°19′	165°45′	41	9/28	07:00 07:05	
12	70°28′	165°15′	42	9/28	15:20 15:25	Sample fouled by *Crysaora*
15	70°18′	164°41′	40	9/29	15:15 15:20	 Net torn sample lost.
18	70°24′	164°09′	40	9/30	07:15 07:20	
19	70°22′	163°16′	28	9/30	13:35 13:45	
21	70°34′	163°16′	36	10/01	14:25 14:30	
23	70°23′	162°24′	20	10/02	10:05 10:10	
24	70°09′	162°57′	18	10/02	16:20 16:25	
26	70°11′	162°52′	16	10/03	08:50 08:55	
28	69°59′	163°17′	19	10/04	07:10 07:15	Qualitative phytoplankton sample also taken
29	70°01′	163°59′	28	10/04	14:00 14:05	Qualitative phytoplankton sample also taken
31	69°45′	163°34′	18	10/05	07:20 07:25	Almost repeats Sta. 8 location
33	69°47′	164°30′	30	10/06	03:50 03:55	
34	69°52′	165°37′	40	10/06	07:45 07:50	
35	69°59′	168°03′	43	10/06	13:20 13:35	
36	70°08′	167°11′	46	10/06	16:40 16:50	
39	69°51′	166°47′	49	10/07	07:25 07:30	 Winch troubles
40	70°18′	166°57′	45	10/07	12:25 12:30	
43	70°30′	168°26′	44	10/08	07:15 07:20	
44	70°11′	168°56′	34	10/08	12:15 12:20	
49	69°48′	168°05′	45	10/09	07:25 07:30	
50	69°38′	167°44′	44	10/09	14:20 14:25	
54	69°24′	167°15′	42	10/10	05:05 05:10	Qualitative phytoplankton sample also taken
55	69°13′	166°52′	38	10/10	12:30 12:35	Qualitative phytoplankton samplo also taken
60	68°57′	166°25′	35	10/11	10:50 10:55	Phytoplankton net lost
62	69°06′	166°02′	25	10/12	07:40 07:50	
63	69°14′	165°56′	32	10/12	11:35 11:40	

Station	Position Lat. N.	Long. W.	Sampling depth (m)	Date	Times BST	Comments
64	69°25′	166°29′	36	10/12	14:55	
					15:00	
69	69°50′	167°23′	44	10/13	09:35	
					09:40	
72	69°19′	165°11′	27	10/14	09:10	Garbage in sample
					09:20	Winch troubles
73	69°33′	164°37′	24	10/14	14:20	
					14:25	
78	69°27′	165°38′	30	10/15	08:40	
					08:45	
85	69°13′	164°45′	20	10/16	07:15	
					07:20	Ice in net
86	69°05′	165°05′	20	10/16	11:00	
					11:05	
87	69°04′	165°36′	20	10/16	14:15	
					14:20	
90	68°54′	166°40′	42	10/17	07:05	
					07:10	
91	68°54′	167°24′	44	10/17	13:10	Insufficient
					13:15	preservative

Table 2.—Preliminary list of the zooplankton collected with the 0.5–m dia., #0–mesh plankton net from the eastern central Chukchi Sea during WEBSEC–70, 27 Sept.–17 Oct. 1970.

Coelenterata
- Hydromedusae
  - *Aglantha digitale* (O. F. Muller)
  - *Melicertum octocostatum* (M. Sars)
  - *Staurophora mertensi* Brandt[1]
  - *Obelia* sp.
- Scyphomedusae
  - *Aurelia aurita* (Linneaus)[2]
  - *Chrysaora melanaster* Brandt[2]
  - *Cyanae capillata* (Linneaus)[2]

Ctenophora
- Lobata
  - ? *Bolinopsis infundibulum* (O. F. Muller)[2]

Nematoda

Bryozoa-cyphonautes

Annelida
- Polychaeta (adults)
- Polychaeta (larvae of several species)

Arthropoda-crustacea
- Cladocera
  - *Evadne nordmanni* Loven
  - *Podon leuckartii* G. O. Sars
- Copepoda-calanoida
  - *Acartia longiremis* (Lilljeborg)
  - *Calanus finmarchicus* (Gunnerus)
  - *Calanus tonsus* Brady
  - *Centropages abdominalis* Sato
  - *Derjunginia tolli* (Linko)
  - *Epilabidocera amphitrites* (McMurrich)
  - *Eucalanus bungii* Giesbrecht
  - *Eurytemora herdmani* (Thompson & Scott)
  - *Metridia lucens* Boeck
  - *Pseudocalanus ? gracilis* Sars
  - *Pseudocalanus minutus* (Kroyer)
  - *Tortanus discaudatus* (Thompson & Scott)
  - Unidentified copepodites
- Copepoda-Cyclopoida
  - *Oithona helgolandica* Claus
- Copepoda-Harpacticoida
- Copepod naupli
- Cirripedia-Thoracia
  - Balanomorpha naupli
  - Balanomorpha cyprids
- Malacostraca
- Mysidacea
  - *Acanthomysis* sp.
  - *Mysis* sp.
- Cumacea
- Isopoda
  - Epicaridea cryptonscids
- Amphipoda-Hyperiidea
  - *Hyperia* sp. (juveniles)
  - *Hyperoche medusarum* (Kroyer) (juveniles)
  - *Parathemisto libellula* (Lichtenstein)
  - *Parathemisto pacifica* Stebbing
- Amphipoda-Gammaridea
  - Oedicerotidae (3 or 4 species)
  - Phoxocephalidae
  - Unidentified (3 or 4 species)
- Euphansiacea
  - *Thysanoessa inermis* (Kroyer)
  - *Thysanoessa raschii* (M. Sars)
- *Thysanoessa* sp. (larvae)
- Decapoda-Caridea
  - *Pandalus goniurus* Stimpson
  - Hippolytidae-(zoea)

- Decapoda-Brachyura
  - Oxyrhyncha-(zoea)
  - Oxyrhyncha-(megalopa)
- Decapoda-Anomura
  - *Pagurus* sp. (zoea)
  - *Pagurus* sp. (glauthoe)

Molluska
- Gastropoda
  - *Clione limacina* (Phipps)
  - *Spiratella helicina* (Phipps)
  - Unidentified veligers
- Lamellibranchiata
  - Unidentified veligers

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[1] Frequently seen but not taken in any of the samples.
[2] Seen more often than taken in samples.
[3] All specimens too damaged for positive identification.

Chaetognatha
- *Sagitta elegans* Verrill

Echinodermata
- Echinoidea (pleutei)
- Asteroidea (bipinnaria)

Tunicata
- Larvacea
  - *Fritillaria borealis* Lohmann
  - *Oikopleura vanhoeffeni* Lohmann
- Ascidacea-(larvae)

Vertebrata-Pisces
- Gadidae
  - *Boreogadus saida* (Lepechin) (juv.)
- Pleuronectidae-(larvae)

Preliminary Report on the Fish Collected on WEBSEC–70

JAY C. QUAST[1]

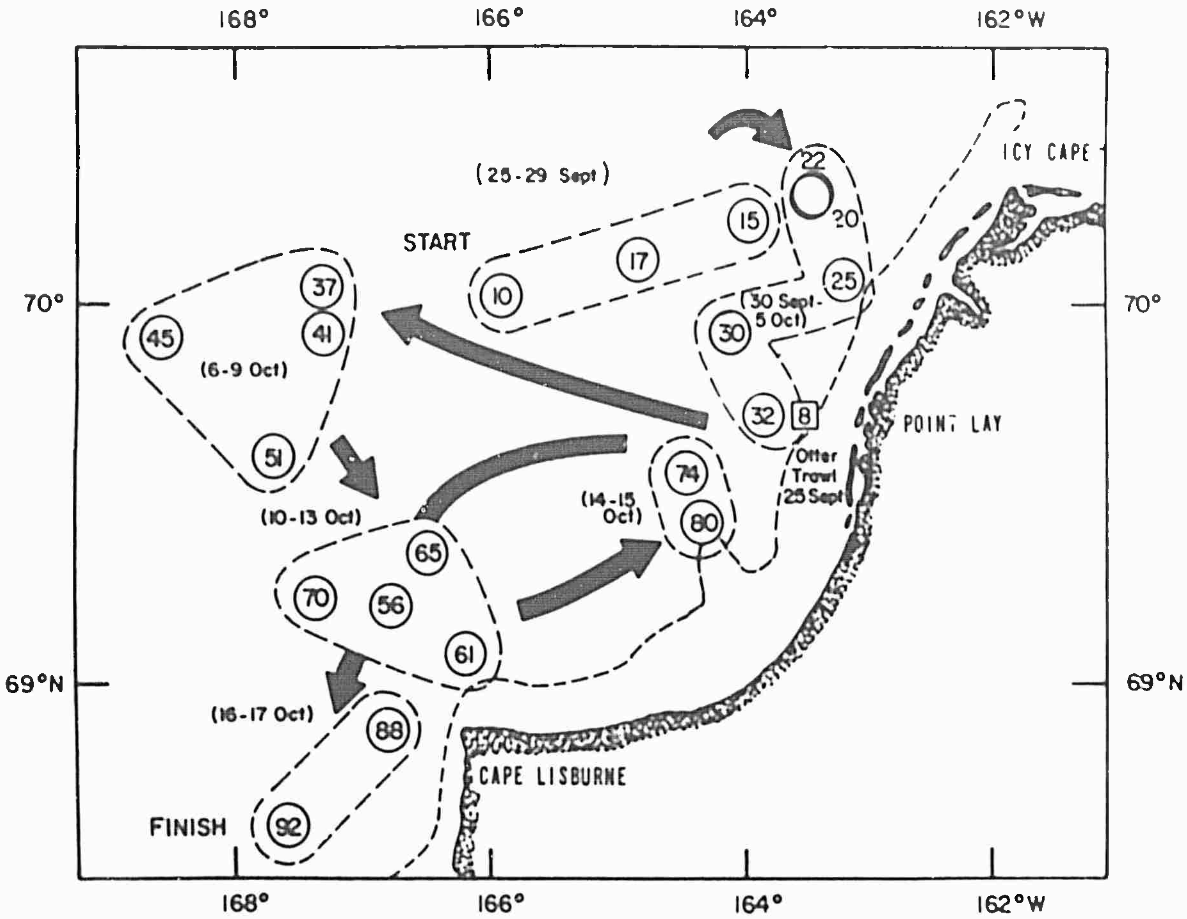

Figure 1.—Positions and sequence of trawling stations during WEBSEC–70. Circles indicate stations on which Isaacs–Kidd trawl was used, square indicates use of otter trawl.

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Table 1.—Station data for WEBSEC-70 fish trawl stations.

Station	Date and inclusive time (Bering Standard)			Approximate position Latitude	Longitude	Depth of water (m)	Hauls No	Type[1]	and depths (m)[2]
8	Sept.	25	(1115-1253)	69°45'	163°34'	26	2	B	26, 26
10	Sept.	27	(1917-2207)	70°04'	165°57'	44	4	R	11
14	Sept.	29	(0518-0817)	70°17'	165°02'	51	4	R	11
16	Sept.	29	(1721-2002)	70°16'	163°58'	53	4	R	11
20	Sept.	30	(1740-2025)	70°20'	163°24'	42	4	R	12
22	Oct.	1	(1734-2103)	70°20'	163°25'	35	4	R	12
25	Oct.	2	(1731-2036)	70°07'	163°14'	33	4	R	12
30	Oct.	4	(1756-2137)	69°58'	164°07'	31	5	M	2, 5, 10, 13, 19
32	Oct.	5	(1831-2104)	69°48'	163°49'	26	4	R	12
37	Oct.	6	(1727-1956)	70°07'	167°38'	49	4	R	12
41	Oct.	7	(1752-2014)	69°57'	167°31'	44	4	M	10, 10, 12, 22
45	Oct.	8	(1816-2058)	69°57'	168°38'	44	4	M	2, 9, 13, 20
51	Oct.	9	(1744-2024)	69°36'	167°36'	48	4	M	2, 7, 14, 20
56	Oct.	10	(1940-2229)	69°14'	166°53'	44	4	M	2, 9, 18, 23
61	Oct.	11	(1755-2015)	69°05'	166°13'	29	4	M	8, 13, 16, 23
65	Oct.	12	(1755-2016)	69°21'	166°45'	36	4	M	8, 13, 16, 22
70	Oct.	13	(1735-1958)	69°12'	167°38'	39	4	M	8, 13, 18, 22
74	Oct.	14	(1723-1946)	69°35'	164°29'	22	4	M	2, 8, 13, 18
80	Oct.	15	(1814-2055)	69°27'	164°43'	30	4	M	2, 8, 13, 22
88	Oct.	16	(1917-2205)	68°55'	166°47'	45	4	M	2, 11, 24, 40-45
92	Oct.	17	(1733-2014)	68°36'	167°41'	54	4	M	2, 13, 17, 33

[1] Hauls approximately 30 minutes at depth. All hauls except those at station 8 were made with a 6-foot diameter Isaacs-Kidd trawl with 76 mm (stretched measurement) webbing and 13 mm liner. Hauls at station 8 were made on bottom with a shrimp try net, with 10-foot opening and 38 mm webbing. M = multi-depth hauls with 6-foot Isaacs-Kidd trawl, B = shrimp try net on bottom, and R = replicated hauls at single depth with 6-foot Isaacs-Kidd trawl.

[2] Depth of footrope or depressor.

Table 2.—Fish species collected during WEBSEC-70.

Family, species	Life history stages	Temperature (C) at presumed depth of collection
Clupeidae:		
Clupea harengus Linnaeus. Herring	Early juvenile	0.8
Osmeridae:		
Mallotus villosus (Müller). Capelin.	Postlarvae, juveniles	-1.5 to 3.3
Gadidae:		
Boreogadus saida (Lepechin). Arctic cod.	Postlarvae, juvenile	-1.5 to 3.5
Eleginus gracilis (Tilesius). Saffron cod.	Juveniles	-0.9 to 3.5
Lycodes palearis Gilbert. Wattled eelpout.	Juveniles	1.1
Scorpaenidae:		
Sebastes alutus (Gilbert).* Pacific ocean perch.	Early juveniles	1.8, 2.4
Cottidae:		
Artediellus scaber Knipowitsch. Hamecon.	Juveniles, adults	3.4
Enophrys diceraus (Pallas). Antlered sculpin.	Juveniles	0.8
Gymnocanthus tricuspis (Reinhardt). Arctic staghorn sculpin.	Juveniles, adults	-1.5 to 3.5
Myoxocephalus jaok (Cuvier). Plain sculpin.	Early juveniles	0.8 to 3.5
Myoxocephalus scorpioides (Fabricius). Arctic sculpin.	Early juveniles	-1.5 to 3.5
Myoxocephalus verrucosus (Bean). Warty sculpin.	Early juveniles	0.8 to 3.5

Family, species	Life history stages	Temperature (C) at presumed depth of collection
COTTIDAE—(Continued)		
Nautichthys pribilovius (Jordan and Gilbert). Eyeshade sculpin.	Juveniles	0.8 to 3.5
Triglops pingeli Reinhardt. Ribbed sculpin.	Juveniles	2.4 to 3.5
Agonidae:		
Aspidophoroides bartoni Gilbert. Aleutian alligatorfish.	Juveniles	-0.1 to 2.4
Aspidophoroides olriki Lütken. Arctic alligatorfish.	Juveniles	-1.5 to 2.4
Podothecus acipenserinus (Tilesius). Sturgeon poacher.	Juveniles	0.9 to 3.5
Cyclopteridae:		
Liparis bristolense (Burke).	Juveniles, adults	-1.5 to 3.5
Stichaeidae:		
Anisarchus medius Reinhardt. Stout eelblenny.	Juveniles	1.9
Eumesogrammus praecisus (Krøyer). Fourline snakeblenny.	Juveniles	0.9 to 2.5
Lumpenus fabricii (Valenciennes). Slender eelblenny.	Juveniles	-1.5 to 3.5
Stichaeus punctatus (Fabricius). Arctic shanny.	Juveniles	0.8 to 2.4
Ammodytidae:		
Ammodytes hexapterus Pallas. Pacific sand lance.	Postlarvae, adults	-1.5 to 3.5
Pleuronectidae:		
Hippoglossoides robustus Gill and Townsend.* Bering flounder.	Postlarvae	0.8 to 2.3
Limanda aspera (Pallas). Yellowfin sole.	Postlarvae	0.8 to 3.3
Pleuronectes quadrituberculatus Pallas. Alaska plaice.	Postlarvae	0.8 to 3.3

*Provisional identification.

Table 3.- Occurrences of fish species on trawl stations on WEBSEC-70. Species arranged in order of increasing occurrence on the stations. Stations arranged in order of decreasing occurrence of species. Species occurrences were highest in the vicinity of Cape Lisburne and generally lowest in the northeastern section of the sampling area.

Species	Isaacs-Kidd Trawl Stations, Eastern Chukchi Sea																				Total	Otter trawl station
	Lisburne														Northeastern							
	61	70	65	88	10	56	80	32	51	92	16	30	41	45	14	25	74	22	20	37		8
Clupea harengus	X																				1	
Lycodes palearis				X																	1	
Podothecus acipenserinus				X																	1	X
Artediellis scaber																					0	X
Enophrys diceraus	X																				1	
Myoxocephalus jaok	X																				1	
M. verrucosus	X																				1	X
Triglops pingeli			X																		1	X
Anisarchus medius					X																1	
*Sebastes alutus**		X									X										2	
Nautichthys pribilovius	X	X																			2	X
Aspidophoroides bartoni	X		X											X			X				4	
Stichaeus punctatus	X		X		X			X													4	
Liparis bristolense	X	X		X			X				X										5	X
Gymnocanthus tricuspis	X	X	X	X			X										X				6	X
Myoxocephalus scorpioides	X	X	X		X		X							X							6	X
Eumesogrammus praecisus					X			X	X			X	X	X							6	
Limanda aspera	X	X	X	X		X			X												6	
Eleginus gracilis	X	X	X	X		X				X					X						7	X
*Hippoglossoides robustus**	X	X	X	X		X				X			X								7	
Mallotus villosus	X	X	X			X	X	X	X	X		X									9	
Aspidophoroides olriki	X	X			X		X						X	X	X	X		X			9	
Pleuronectes quadrituberculatus	X	X		X	X	X		X	X	X	X	X									10	
Lumpenus fabricii	X	X	X	X	X	X	X	X	X	X	X	X	X			X					14	X
Boreogadus saida	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20	X
Ammodytes hexapterus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20	
Total	19	14	12	11	9	8	8	7	7	7	6	6	6	6	4	4	4	3	2	2	145	11

*Provisional identification.

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